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# **The Special Committee of the Senate on the Northern Pipeline**

## **A SUBMISSION BY DOME PETROLEUM LIMITED**

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## 1.0 EXECUTIVE SUMMARY

### INTRODUCTION

Dome Petroleum was invited by the Senate Committee on the Northern Pipeline to participate in the hearing on the subject of "transportation of petroleum and natural gas North of 60° and any matter related thereto"

Contained in the letter of invitation from Senator Hastings to W.E. Richards, President of Dome were the following questions:

- 1) "has sufficient research and emphasis been committed to exploring all of the options with respect to the various proposed transportation modes?"
- 2) "is there adequate information in existence or will there be adequate knowledge available on which to make decisions both for the North and Canada?"
- 3) "have the safety and economics been adequately addressed?"
- 4) "is Canada in an advantageous position to enjoy the benefits of cold climate technology?"
- 5) "is the regulatory process in place to adequately oversee projects both from the public and sponsor's point of view?"
- 6) "is the regulatory process in need of streamlining?"
- 7) "how well prepared are the various sectors to capitalize on the technical challenge?"
- 8) "how well prepared are the various sectors to bring benefits to Canada generally and the people living in the north in particular?"
- 9) "can we identify expertise, data and/or regulatory deficiencies?"
- 10) "how well prepared is Canada to absorb the industrial requirements of exploration, production, transportation and marketing stages of Frontier development?"
- 11) "how well prepared is Canada to provide the manpower skills required for exploration, production, transportation and marketing stages of Frontier development?"

This presentation deals specifically with the development and transportation of hydrocarbons from the Beaufort Sea.

The document addresses the Senate questions under the following headings:

- General Background
- Future Development
- Research in Support of Development
- Arctic Marine Transportation
- Industrial and Economic Benefits of Beaufort Development
- Decision Making Process

## BEAUFORT DISCOVERIES AND HYDROCARBON POTENTIAL

Dome has been actively exploring in the Beaufort Sea since 1976 when the company brought a fleet of ice-reinforced drillships and icebreaker supply boats into the area. The company currently operates 4 drillships, 8 icebreaking supply vessels, 3 dredges, 4 tugs, several standby boats and other smaller craft and 1 Class 4 icebreaker, the Kigoriak.

The exploration effort has been very successful in corroborating the expectations of geologists who have long predicted that the Mackenzie Delta-Beaufort Sea area would be a major oil and gas producing province. The Dome *et al*, drillship operation has completed 15 wells and is credited with four of the offshore oil discoveries and two gas discoveries. Testing still needs to be carried out on two wells and three have yet to be drilled to total depth.

Delineation drilling is required to establish the commerciality of the offshore discoveries. One successful delineation well was drilled in 1981 offsetting the Kopanoar discovery, and a delineation well is currently drilling an offset to the Tarsiut discovery. Delineation drilling of the Koakoak discovery is planned for 1983, and further drilling at Kopanoar for 1983 and 1984. Of these discoveries Tarsiut is in the shallowest water and therefore has the greatest potential for early production from the Beaufort.

Estimates for Beaufort hydrocarbon potential vary over a range from 6.9 to 34 billion barrels of oil and up to 60 trillion cubic feet of gas. However, the precise potential of the Beaufort should not be an issue at this stage of evaluation since only a few fields would be fully developed by the end of this century. The industry expects to confirm 4.5 to 7.5 billion barrels of oil in the Beaufort by 1990.

Consultants estimates for recoverable oil reserves at Kopanoar range from 270 million barrels to 1.8 billion barrels and at Koakoak from 300 million barrels to 2.0 billion barrels. Estimates have not been released for other discoveries. The threshold reserves level to justify the investment to bring the first Beaufort field on production is approximately 700,000 barrels of recoverable reserves, producing at a rate of 100,000 BOPD, assuming the oil is transported by a marine transportation system. This level could be established by any one of the delineation programs now in progress. Subsequent developments will have a lower threshold level because a significant portion of the supporting infrastructure would be in place.

If the oil was transported by pipeline the minimum threshold level for the first development is estimated to be 2.5 billion barrels of recoverable reserves at a production rate of 350,000 BOPD, based on a 36 inch pipeline.

## CRUDE OIL SUPPLY AND DEMAND

Forecasting the demand for oil is difficult as evidenced by

the range of estimates provided to the National Energy Board at their 1981 hearings and by the NEB's own forecasts. Forecasting supply is equally difficult given the state of evaluation and development of tar sands, frontier areas, and enhanced recovery from conventional reserves.

Critical decision-making based on these projections is risky, given the consequences of erring on the side of undersupply. To achieve energy self-sufficiency by the year 1990, supplies required from the tar sands and the frontiers may approach 700,000 BOPD. [Depending on the choice of supply and demand forecast] The only prudent move that can be taken at this time is one towards establishing production from all sources including the tar sands, the East Coast, and the Beaufort.

Once production systems have been established in the Frontiers the pace of frontier development can be controlled to meet the real demand.

## PRODUCTION SYSTEMS FOR THE BEAUFORT

Research and development carried out concurrently with the Beaufort exploration program has provided the basic data required to design safe systems for permanent offshore drilling and producing systems. A progressive technology approach has been used to develop the optimum designs. For example man-made gravel and sand islands will be used as foundations for permanent drilling and producing systems. The first man-made island in the Beaufort was built by Esso in 4 feet of water in 1972. This was followed by 17 more islands built in the landfast ice zone in water depths increasing to 60 feet. Using the experience and technology from these islands, a prototype permanent island was designed and built at Tarsiut as a test project, and as a foundation for drilling delineation wells. This island is topped with concrete caissons and is located on the edge of the moving ice zone, where it provides a full scale experiment for future systems.

The first production island can be built when about 300-400 million barrels of oil reserve are accessible from a single island. This could be achieved with the delineation program planned for Tarsiut in 1982. The present test island could be converted to a permanent production island by additional dredging, establishing the opportunity for production as early as 1985.

Each field may require several islands ultimately, depending on the depth and areal extent of the reservoirs. Wells will be directionally drilled from each island. Production from the islands in any given field will be collected at one larger island for processing and loading aboard tankers. The island operations will be supported primarily with icebreakers operating from shorebases at Tuktoyaktuk and at McKinley Bay about 70 miles northeast of Tuktoyaktuk.

Icebreaking tankers will carry the oil south to eastern

Canadian markets. The tankers will operate on a year-round basis, each carrying the equivalent of about 50,000 BOPD.

Gas production could also be carried by tanker but will more likely be transported via the proposed Dempster Lateral pipeline to the proposed Alaska Gas Pipeline system.

## PRODUCTION LEVEL

Regular Beaufort production is scheduled to commence in 1986 from a single island, presumably in the Tarsiut field. Thereafter the growth of production will depend on how many additional islands at Tarsiut or other discoveries are developed and brought on production. This determination will likely be made by the government and will be a function of need.

An upper limit has been established based on the technical feasibility and a lower limit based on economics. The expected value will lie between the two. In 1990 the range is 200,000 to 450,000 BOPD and the expected value is 300,000 BOPD. In the year 2000 the range is 200,000 to 1.2 million BOPD, and the expected value approaches 800,000 BOPD. Dome's estimate of expected demand is based on the NEB oil supply deficiency estimate from 1990 — 2000 and assumes that approximately half of the deficiency will be supplied from the Beaufort.

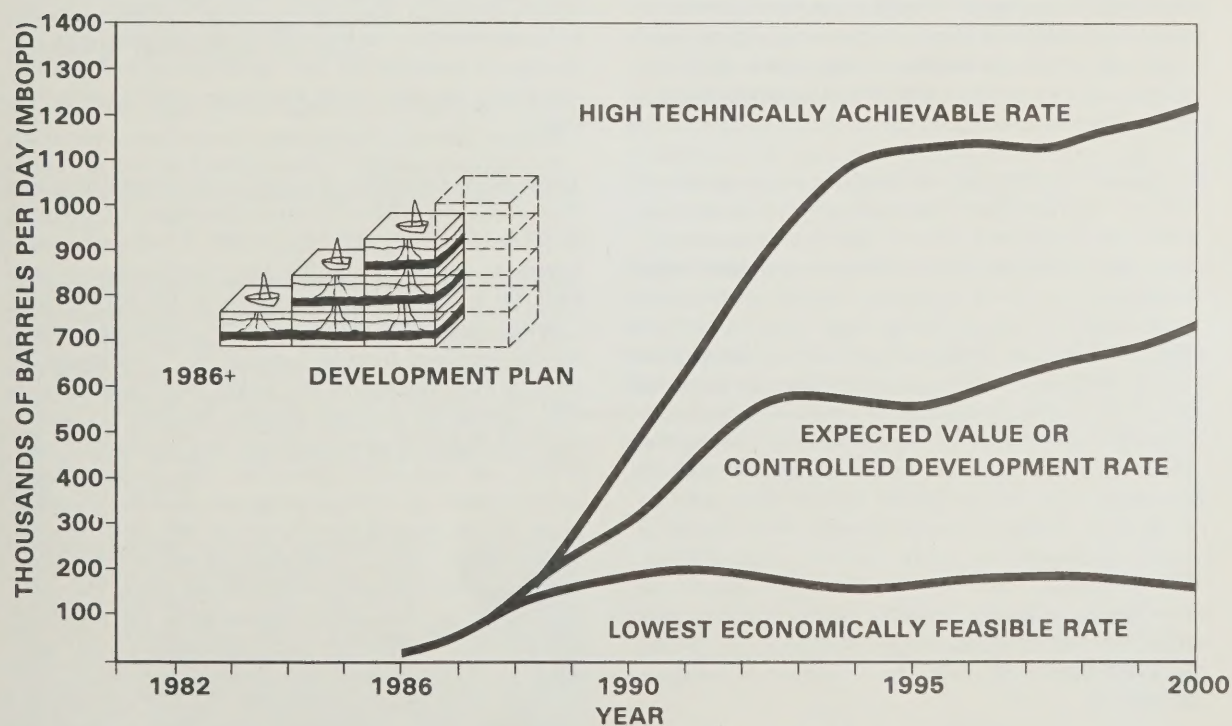
It should be noted that these production forecasts and the proposed development schedule for Tarsiut are very similar to those provided previously in Dome's presentation to the National Energy Board in 1981.

## RESEARCH IN SUPPORT OF DEVELOPMENT

In support of ongoing and future petroleum industry activities, a great deal of research has been performed in the Beaufort Sea-Mackenzie Delta region. Extensive ice and other physical research programs over the past decade have demonstrated that offshore petroleum operations in ice infested waters are clearly feasible now and in the future.

To support the proposed tanker transportation scheme, a highly sophisticated remote sensing, communications and navigation system (REMSCAN) is being developed; it will ensure the safest and most efficient passage of icebreaking tankers through the Arctic seas.

Major strides have been made in the field of oilspill prevention, countermeasures and clean-up under Arctic conditions. Dome has developed a specially trained team of personnel and has available to it one of the largest aggregations of oilspill cleanup equipment in the country at Tuktoyaktuk. This combined with the industry's increased understanding of the behaviour of oil in ice, and the new techniques-technologies developed to deal with spills under



*A range of production rates can be achieved depending on the need for oil and the numerous other variables which will influence development. The likely production rate will probably fall between the highest technically achievable rate, and the lowest economically feasible rate.*

these conditions, allows us to conclude that effective responses to oilspill incidents can be mounted.

Biological research programs have and are continuing to be carried out to address all important issues related to offshore activities. To date no significant biological problems have been detected, and with the application of appropriate measures combined with continued monitoring, none are expected in the future.

## **TANKERS AND PIPELINES**

Dome believes that first production from the Beaufort Sea can be achieved on a small scale as early as 1985, with the use of an Early Production System, combined with transportation of the oil to market by icebreaking Arctic Tanker. The essential experience gained by initiating production in this manner will itself be a major accomplishment, and would go far in promoting the controlled incremental development of the Beaufort's hydrocarbon resources. Beyond initiating the first flow of oil by tanker, there remains the question of how increasing production from the Beaufort Sea should be transported to market. All of the proponents acknowledge that both pipelines and tankers are feasible under certain conditions, and that the environmental and socio-economic impacts of both systems can be maintained within acceptable limits.

At this point it is fair to say that some proponents lean towards pipelines, while others lean towards tankers. The favouritism does not arise because of a wanton desire to build a fleet of tankers or to build a new Arctic pipeline. It comes from individual interpretations and judgements as to the reaction of governments to proposals to build one system or the other when a plan of development is submitted for approval.

It is also influenced by the individual company's position in the area — including such factors as number of discoveries, size of fields discovered, stage of exploration and development, and the size and nature of the proponents' activities elsewhere.

However, based on Domes examination of the various factors, the company believes that only through the use of Arctic tankers, can the Beaufort Sea make an early contribution to Canada's crude oil supply position. The pipeline option does not begin to become practical until oil throughput rates exceed 350,000 BOPD, representing a 36" diameter pipeline. It would be highly unlikely that oil production through this option could be achieved before 1990. Until then, the advantages of tankers, in terms of many factors including flexibility, incrementability, cost economics, and industrial and social development strategies weigh significantly in favour of their use to transport Beaufort oil.

## **ARCTIC MARINE TRANSPORTATION**

Oil is the most common and largest cargo shipped by sea in

the world. Subject to receiving approvals, Dome proposes to transport Beaufort oil to market with powerful 200,000 tonne, double-hulled icebreaking oil tankers. The Arctic tanker will combine the best features of both icebreakers and tankers. The final product will be the strongest, safest tankers that may ever be built, operated by highly skilled, motivated, and responsive personnel.

Extensive ice research programs have established ice conditions in the Northwest Passage, and ice-related design criteria for Arctic tankers are well in hand. Through research and progressive technological development, Dome has determined the required design characteristics for future Arctic tankers.

To regulate shipping in the Arctic the Federal Government is establishing a Control Authority. This authority, combined with the sophisticated vessels of the future and the equally sophisticated navigation aids, should ensure the safest possible transit of ships through the Northwest Passage.

## **NORTHERN IMPLICATIONS AND BENEFITS**

During the six years that Dome has been active in the Beaufort Sea region, one of the most important guiding principles has been to maximize opportunities for northerners and to minimize possible negative effects of the operations.

Based on several years of accumulated northern experience, Dome, in cooperation with government and the local communities, has been able to develop principles and implement strategies for local participation and benefits which have provided visible advantages to the people of the region.

The number of northern employees on the payroll has risen dramatically since Beaufort operations began, from a total of 127 hired in 1976 to 389 hired in 1981. Total employment income to northerners during this period increased from \$400,000 in 1976, to approximately \$7,500,000 in 1981. Likewise, support of businesses in the Northwest Territories has increased from \$2.9 million for 77 businesses in 1976, to \$19.3 million for 164 locally based businesses in 1981. During the next two decades, Beaufort Sea operations will change from seasonal and medium-scale to year-round and large-scale operations. The current Dome socio-economic policies and programs, modified as appropriate, will be applied over the period 1982-2000. Specific socio-economic policies and programs will be formulated in conjunction with specific development plans. The company envisages tremendous opportunities for beneficial participation and lifestyle improvements for local residents, provided that balanced planning, regulations, and controls are implemented now. To this end, several programs were initiated in 1981 and more will be developed in the future.

Regarding future northern employment opportunities, a labour force much larger than can be supplied by the local population will be needed to build and operate all of the facilities which will eventually be required. As the labour force expands, an increasing proportion of it would be needed year-round rather than on a seasonal basis. By July 1981, industry had developed a preliminary 'Manpower Plan and Delivery System' in conjunction with the engineering scenarios for development.

The skills required for future developments will vary from very specialized engineering and scientific skills to the more routine labour type skills. In July 1981, the Regional Government for the Western Arctic and industry began to develop a 'Five Year Action Plan' to ensure that education systems in the Inuvik Region would meet the needs of the communities, the individuals, and industry.

## **IMPACTS OF MARINE BASED DEVELOPMENT ON THE CANADIAN ECONOMY**

Considerable benefits have accrued to Canada as a result of the ongoing exploration program and more can be expected as operations progress to the production phase. As an example, in 1981, total Beaufort-related direct expenditures were in the order of 482.0 million dollars, while the 1982 budget is expected to approach 700 million dollars. Capital items which have been purchased or constructed in Canada over the past few years have included many of the supply boats and smaller vessels, the ice-breaker Kigoriak, the caissons and drill package for Tarsiut and the Tuktoyaktuk base camp.

Beaufort Sea development appears to complement all of the Government's priority strategic policies and programs, namely Industrial Development, Reserves Development, Transportation and Technology Development and Human Resources.

With the aid of an economic model, Dome has projected the possible impacts of various levels of Beaufort development on the Canadian economy. The implications will extend across the country and will include raising the Gross National Product, improving the Government's revenue standing — perhaps to a surplus level, improving the current account balance, and creating tremendous employment opportunities.

In comparing the economic implications of transporting oil by tankers as opposed to pipeline, the major difference is the fact that first oil can be achieved at a much earlier date with tankers than with a pipeline. Moreover, the employment profile and steel demands for a marine-based scenario are much more gradual over time. The pipeline option has a higher overall purchase requirement and although Ontario is the prime recipient of direct purchases in both instances, the tanker scenario spreads more of its benefits to Quebec and the Maritimes, while the pipeline

scenario is most beneficial to the West and Ontario in the early years.

On a more national basis, Canada has tried to encourage industry to link industrial development and natural resources and to assist regional benefits programs. In the case of Beaufort Sea development plans, Dome has responded by focusing considerable attention on the marine component including developing plans for the construction and operation of a world-scale shipyard in southern Canada. The scenario of creating the technical and physical capability in Canada to efficiently build the large ships and marine structures which will be needed is well advanced.

The investments made by Dome in both financial and human resource terms have contributed a solid base of research and development for the manufacture of large vessels and structures for the Arctic and elsewhere. Given the opportunity to follow through on its shipbuilding plans, Dome believes Canada will be placed in a uniquely strong position to benefit from this valuable technology.

## **DECISION-MAKING PROCESS**

Canada's North is one of the most regulated areas of the country, ensuring that development is carried out in an environmentally and socially acceptable manner.

Nevertheless, industry is generally apprehensive about making the major financial commitments required to bring the Beaufort into production at an early date because of the apparently incomplete or often unclear production related regulatory procedures which must be pursued prior to receiving clearances. Furthermore, it should be noted that because of the short "open water nature" of Beaufort operations, even seemingly minor delays of a few months in receiving approvals can result in significant production related delays of a year or more.

**For this and other reasons, Dome, and we believe industry in general, would strongly recommend that Government policy enunciate an early "Approval in Principle" for the development of Beaufort oil and gas to proceed expeditiously in the interest of the national economy.** We also believe that Government should be encouraged to pursue its present course of vesting considerable authority in fewer centralized government agencies.



## **SUMMARY OF SECTION 2.0**

### **GENERAL BACKGROUND**

2.1 Dome Petroleum Limited has recently become the largest Canadian-owned oil company. The company is actively engaged in all aspects of the petroleum industry, with most of its exploration activities being carried out in western Canada, the Beaufort Sea and the Arctic Islands.

2.2 Dome has been active in the High Arctic since 1961, and the Beaufort since 1976. During this time it has learned a great deal about operating in the Arctic environment, to the point where it now feels confident that year-round operations in the Beaufort are entirely feasible.

2.3 In the Beaufort, Dome operates 4 ice-reinforced drillships, together with a fleet of icebreaking and other support vessels, a major base at Tuktoyaktuk and a man-made harbour at McKinley Bay. Dome also recently built the Arctic's latest, most innovative, caisson-retained exploration island at Tarsiut.

2.4 Since Dome began drilling in the offshore Beaufort, 15 wells have been drilled, resulting in 4 oil discoveries, 2 gas discoveries and two indicated but untested oil wells.

2.5 The most recent recoverable reserve estimates are 270 million to 1.8 billion barrels of oil at Kopanoar, and 300 million to 2.0 billion barrels of oil at Koakoak. The Tarsiut discovery is awaiting the results of the current delineation well which will be tested in the spring of 1982.

2.6 The most recent NEB oil demand projections project a shortfall in oil supply as large as 600,000 barrels/day by 1985 and 700,000 barrels/day by 1990. Under these circumstances Dome believes the only prudent move that can be taken is one towards establishing production from all sources including the tar sands, East Coast, and the Beaufort.



## 2.0 GENERAL BACKGROUND

### 2.1 DOME PETROLEUM — THE COMPANY

Dome Petroleum Limited is a Canadian public company which was incorporated in 1950. Its head offices are located in Calgary, Alberta.

Dome is engaged in the exploration for, and the production, transportation and marketing of crude oil, natural gas and natural gas liquids in Canada and the United States. Together with its associate, Dome Canada, the company is conducting one of the most active oil and gas exploration and development programs in the country.

Exploration activities are carried out mainly in western Canada, the Beaufort Sea and the Canadian Arctic Islands. New exploratory drilling records for Dome were set during 1980 in both footage and number of wells drilled. Exploratory drilling in Dome interest wells in Canada during 1980 totalled 1,995,000 feet, an increase of 13% over the 1979 footage. This represented approximately 12% of the total exploratory footage drilled in Canada during 1980. Addi-

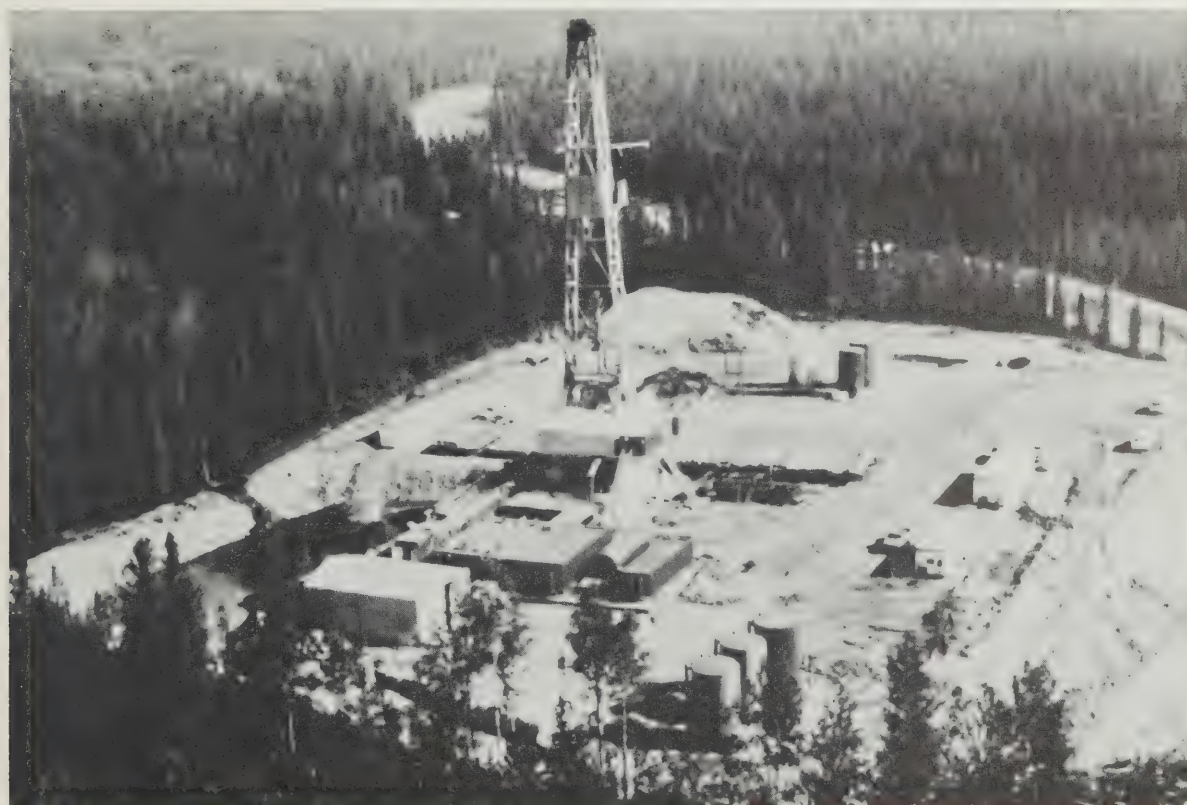
tional exploratory work is being carried out in the United States, and through an associate company, in the North Sea. In the Beaufort Sea, marine contract drilling services are provided by Dome's fleet of ice-reinforced drillships and supply vessels.

The company's major producing properties are located in the provinces of Alberta, British Columbia and Saskatchewan. Dome holds a major interest in and operates an integrated natural gas liquids system, which includes extraction and gathering facilities in Alberta, and distribution facilities in eastern Canada and the United States. Dome is also a major participant in an Alberta ethane supply and light hydrocarbon liquids pipeline system to eastern Canada and the United States.

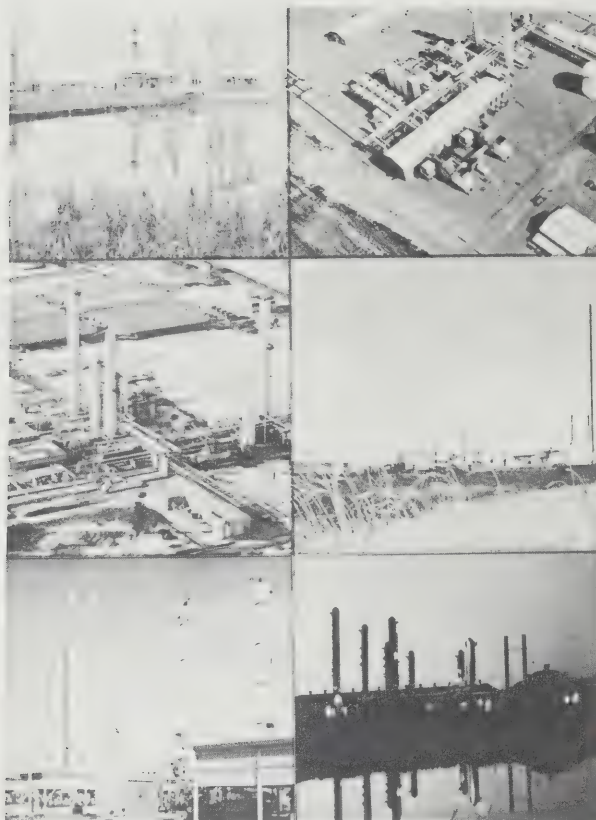
### 2.2 ARCTIC EXPERIENCE

Since the Senate Committee is particularly interested in northern development-related issues, we will take this opportunity to provide more detail on Dome's Arctic experiences.

#### (a) Arctic Islands



**PLATE 2.1.1** As one of Canada's most active exploration companies, Dome drilled a total of 1,995,000 feet of hole in Dome interest wells in Canada during 1980. This 1980 footage represents approximately 12% of the total industry exploratory footage drilled in Canada during the year. Most of the footage drilled is at conventional land based sites as this one in west-central Alberta.



**PLATE 2.1.2** *Dome's processing plant at Empress, in Southeastern Alberta, where natural gas liquids and ethane are extracted. Part of the ethane is used as feedstock for a major ethylene plant in Central Alberta and the remainder is injected with other NGL's into the Cochin pipeline.*



**PLATE 2.1.3** *Dome is operator of the 1,900 mile Cochin Pipeline System which transports ethane and ethylene, surplus to Alberta's requirements, to Eastern Canadian and United States markets.*

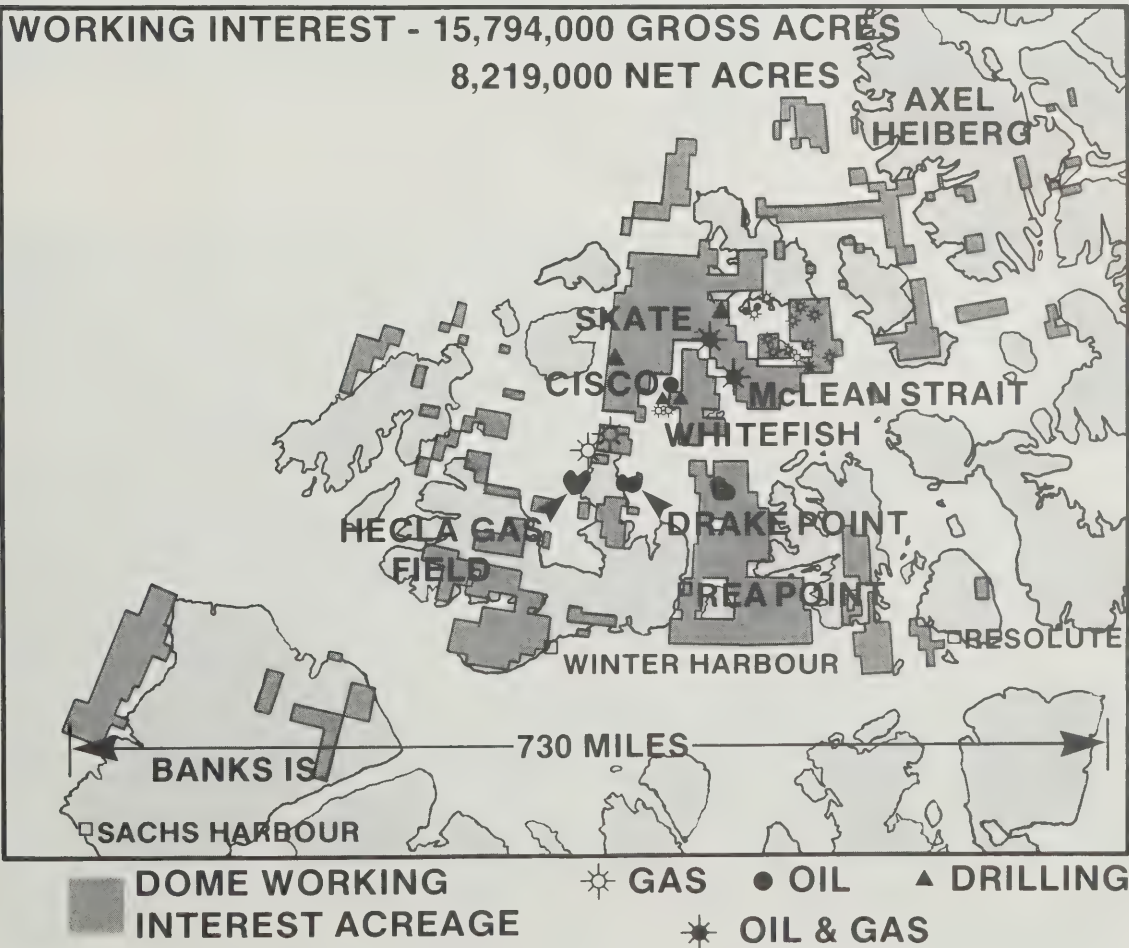
Dome has been active in Arctic exploration for many years, having drilled the first exploration well at Winter Harbour on Melville Island in 1961. Dome's acreage holdings in the Canadian Arctic Islands on December 31, 1980 totalled 16,318,000 gross (9,410,000 net) working interest acres (Figure 2.2.1). Dome was the initial operator for Panarctic Oils Ltd. ("Panarctic"), a very active petroleum exploration company in this region.

In May, 1979 Panarctic announced a large natural gas discovery at Whitefish H-63, southwest of Loughheed Island, within five miles of Dome's interest acreage. A second well was completed on this structure in early 1980. Panarctic has estimated total gas reserves at Whitefish to be 2.4 trillion cubic feet.

In the 1979-80 winter, Dome participated in two offshore wells, Panarctic Dome Balaena and Panarctic Ocean Char, drilled from ice islands on Dome interest lands 17 miles southeast of King Christian Island. Panarctic tested non-commercial oil and gas at Balaena and has estimated gas reserves of 377 billion cubic feet at Char.

Dome participated, during the 1980-81 winter drilling season, in two additional offshore ice island wells, Panarctic Dome Skate B-80 and Dome's Maclean Strait I-72, 10 miles east of Loughheed Island. Panarctic, as operator, announced in March 1981, an oil discovery at Skate with a flow rate of 775 barrels per day and in April, 1981, a gas discovery at Maclean which flowed at a rate of 5.8 million cubic feet of gas per day.

Dome is a 20% participant in the Arctic Pilot Project. This project, operated by Petro Canada, is designed to gather and liquefy 225 million cubic feet per day of natural gas from the Drake Point and Hecla gas fields on Melville Island and to deliver the liquefied natural gas to Eastern Canada in icebreaking tankers on a year-round basis. On October 15, 1980, the Arctic Pilot participants filed for Canadian federal regulatory approval with the National Energy Board.



**FIGURE 2.2.1** Dome's acreage holdings in the Arctic Islands at December 31, 1980. Acreage holdings totalled 16,318,000 gross and 9,410,000 net working interest acres.



**PLATE 2.2.1** *Panarctic Oil's Whitefish discovery gas well drilled from an ice platform west of Lougheed Island in the High Arctic.*

#### (b) Beaufort Sea

Since 1967, Dome has held a major exploratory permit position in the Beaufort Sea where it is conducting an active exploration program. Dome's acreage holdings in the Beaufort Sea at December 31, 1980 totalled 11,396,000 gross acres (4,705,000 net acres). Figure 2.2.2 shows Dome's acreage holdings as well as present and proposed Beaufort Sea well locations. Dome Canada will be incurring exploration expenses on these lands for a minimum of the next three years to earn varying interests therein.

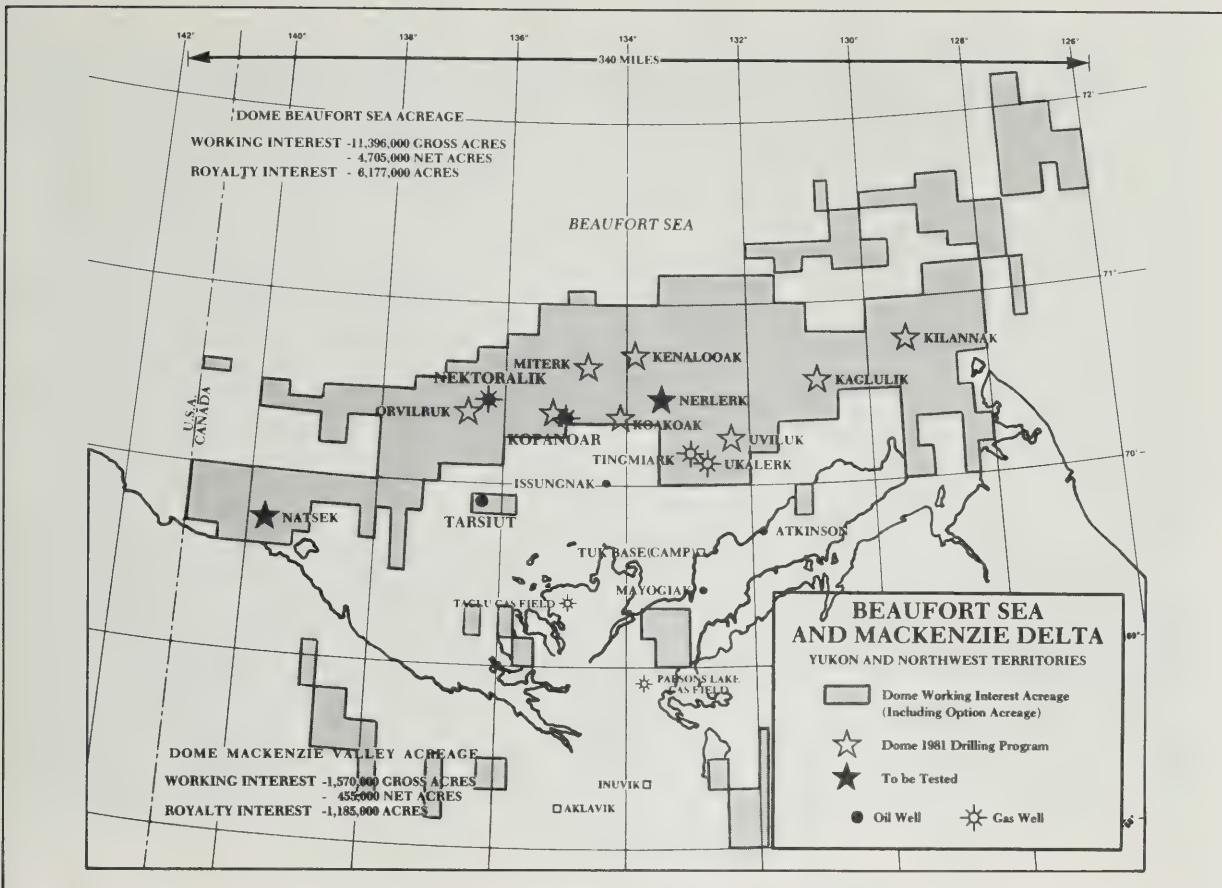
Dome has participated in conducting approximately 22,000 miles of exploratory seismic work in the Beaufort Sea and over 40 attractive geological structures have been identified on acreage in which the company has a working interest or the right to earn an interest. Exploratory drilling in the Beaufort Sea commenced in 1976. To date, Dome has drilled 15 Beaufort Sea wells which have resulted in four oil discoveries, two gas discoveries, two indicated but untested oil wells and one abandonment. The remaining wells have been drilled to less than projected total depth. Since the Beaufort area is of primary interest in this submission, it will be dealt with in further detail.

## 2.3 BEAUFORT ACTIVITIES

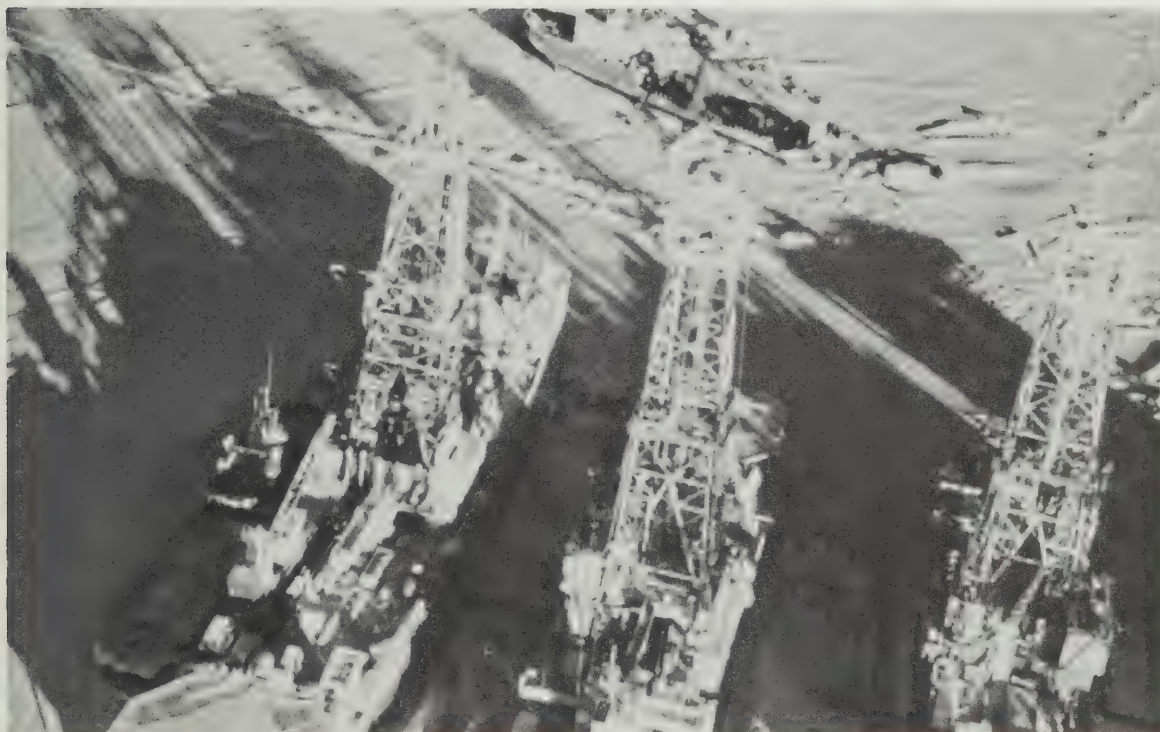
Dome, through its subsidiary Canadian Marine Drilling

Ltd. ("Canmar") commenced its exploratory drilling program in the Beaufort Sea during 1976 with three ice-reinforced drillships. A fourth drillship was added in 1979. In addition to the drillships, the present drilling fleet includes eight supply vessels four of which are ice class, one Class 4 icebreaker, four ice class support tugs, an ice-reinforced fuel tanker, an offshore crane barge, a floating drydock and six specialty barges. To increase the pace of offshore drilling activity, in 1980 Dome commenced the construction of exploration drilling islands in the offshore Beaufort at the Kaglulik and Tarsiut sites. The Tarsiut island, operated by Gulf, was completed in 1981 and drilling at this site is presently underway. Tarsiut is the world's first caisson retained island built in Arctic waters.

This type of island construction represents a significant step forward in the design and construction of future Arctic offshore platforms. Unlike the more conventional sacrificial beach islands built in the shallower waters of the Beaufort, Tarsiut required much less gravel and sand to complete the structure. Tarsiut was built with a more steeply sloped berm foundation, with a 1 in 5 slope, compared to the more conventional 1 in 15 for previous islands. In addition, because of the use of caissons to break through the water-air interface, the subsea berms end approximately 6 metres (20 ft.) below the waterline.



**FIGURE 2.2.2** Dome's acreage holdings in the Beaufort Sea at December 31, 1980.



**PLATE 2.3.1** Three of Dome's ice-reinforced drillships, several supply ships and at the top of the photo, the icebreaker Kigoriak, while moored in McKinley Bay during the winter of 1979-80.



**PLATE 2.3.2** *One of Dome's eight supply vessels is shown working in icy waters in the Beaufort Sea.*



**PLATE 2.3.3** *Dome's new floating drydock, the Canmar Caren, was brought into the Beaufort during 1981 and is capable of handling all present ships of the Beaufort fleet, including the drillships.*



**PLATE 2.3.4** Tarsiut, the first caisson-retained island in the Beaufort Sea, was completed during 1981. A delineation well is presently being drilled from this island and will be tested in the spring of 1982.



**PLATE 2.3.5** The caissons used in building the Tarsiut island were built in Vancouver at a cost of \$27 million, and were towed by barge to the Beaufort in July, 1981. Each caisson weighs 5,300 tons and measures 80 metres (262 feet) long.



**PLATE 2.3.6** *With the four concrete caissons in position, Tarsiut took form in the Beaufort Sea. After being filled with sand and topped off with a gravel surface, drilling equipment was put in place using large cranes.*

Tarsiut also serves as a research laboratory, having been equipped with more than a million dollars worth of instrumentation to measure ice and other forces throughout the life of the island. This preliminary experience, together with the research data generated, are being directed into the design of exploration islands projected for the Uviluk and Koakoak areas, and will make a major contribution to the design of future production facilities.

To support the exploratory drilling effort, a sizeable shore-base is operated by Dome at Tuktoyaktuk. The base has expanded over time and presently occupies approximately 22 hectares. This includes an 8 hectare storage area, a dock and staging area and accommodation facilities for 400 people. The base facilities include an administration complex, warehouses, light steel fabrication and machine shops and a fire hall.

The base is serviced by air from the Tuktoyaktuk airport, which accommodates the company's regular 737 crew change flights and numerous smaller fixed wing aircraft and helicopters.

During the first three years of operation in the Beaufort, Dome's drillships were anchored through the winter at natural harbour sites located at Herschel Island and at Cape Parry. This posed various operational difficulties for the company and in 1979 Dome received permission to create a new winter anchorage at McKinley Bay on the

Tuktoyaktuk Peninsula. A large cutter suction dredge known as the Aquarius was brought in, and by the end of the 1979 open water season, had dredged a navigation channel and basin in McKinley Bay.

During 1980 and 1981 the McKinley Bay harbour was enlarged to accommodate the expanding drilling fleet. In the process, an island was built on the north side of the mooring basin. This island, which serves to protect the ships anchored in the basin has grown to 63 hectares in size. Geotechnical studies conducted on the island have shown it to be very adequate as a foundation for future support base facilities and activities.

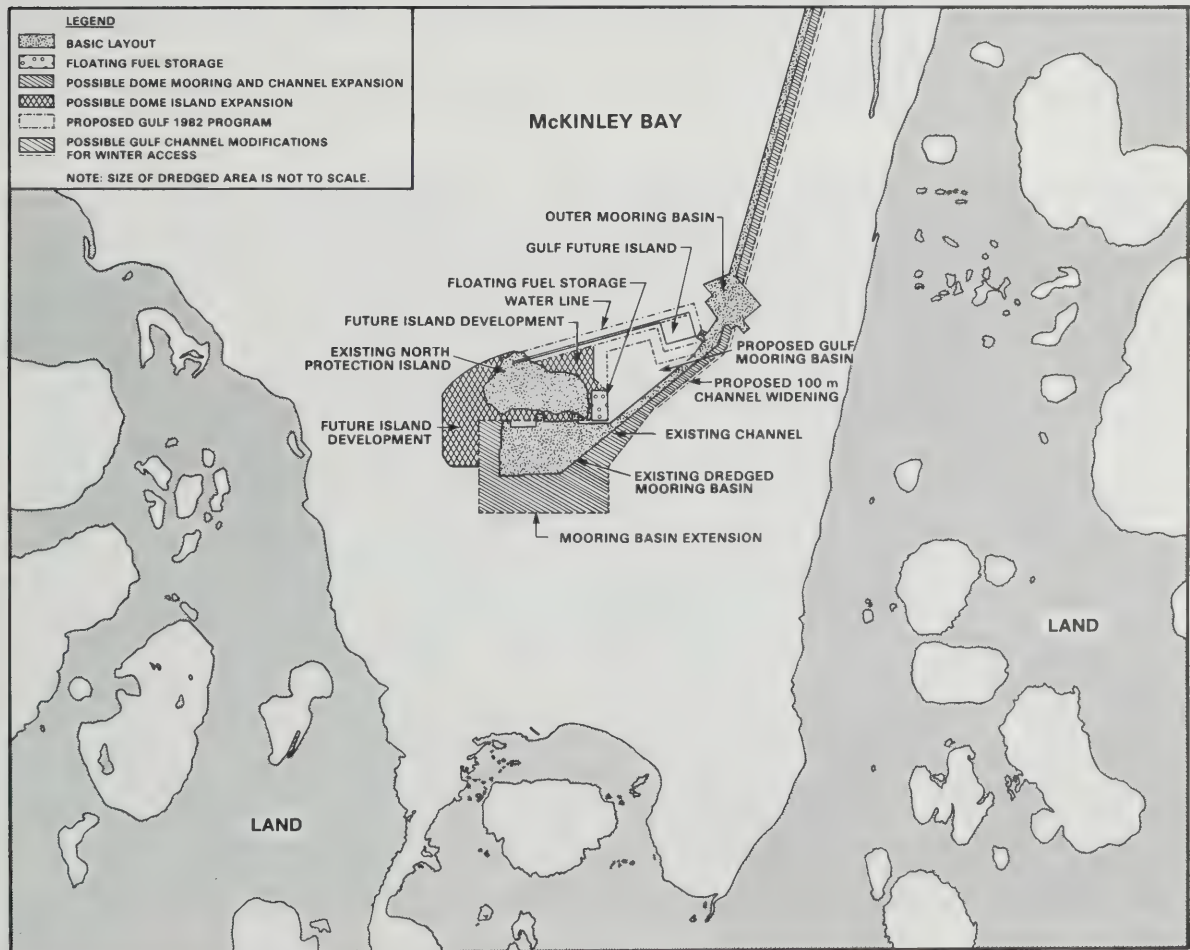
Dome, in consultation with other operators and the Federal Government, is presently developing plans to use the island as a major support base to service year-round exploration drilling and the initial future production development activities (Figure 2.3.1).

## 2.4 DISCOVERIES

Since 1976, Dome has drilled 15 wells in the Beaufort Sea. These include 4 oil discoveries, 2 gas discoveries, 1 oil confirmation well, 1 gas confirmation well, 5 suspended wells which require additional drilling and/or testing, 1 gas indication which was abandoned due to mechanical problems, 1 well which is presently drilling, and only 1 well which was dry and abandoned.



**PLATE 2.3.7** Dome's support base at Tuktoyaktuk provides accommodations for 400 people, warehousing, storage, yards, transportation and communications facilities to support the offshore drilling program.



**FIGURE 2.3.1** Existing and proposed future development of McKinley Bay harbour.



**PLATE 2.3.8** The cutter suction dredge *Aquarius* was brought to the Beaufort in 1979 to dredge an overwintering harbour at McKinley Bay. Since then it has been used to perform a variety of jobs including enlarging the McKinley Bay harbour, providing sand for the Tuktoyaktuk water reservoir, and to help with the building of Tarsiut.



**PLATE 2.3.9** Construction of the McKinley Bay harbour began in 1979. Since then it has been enlarged to accommodate the growing marine fleet. In the process an island of sand now covering an area of 63 hectares was built. The island is suitable for development and plans are being formulated to create a major year-round base on this site to support future production.

This is an exceptionally high ratio of discoveries to wells drilled for a new exploration basin, and indicates that the Beaufort Sea has a very high potential to become a major source of hydrocarbon production.

(a) Kopanoar

Two wells have been drilled on the Kopanoar structure, and both have encountered a significant accumulation of oil. The M-13 well, which was completed and tested in 1979, produced oil at rates over 6,000 barrels per day from a reservoir depth of 3,500 metres. Engineering estimates of its productive capacity show it to have a potential of 12,000 barrels of oil per day. The 2I-44 well was drilled higher up the structure as a step-out from M-13 to confirm the presence of oil. It was tested in 1981 and produced oil at a rate of 1,345 barrels per day from a depth of 3,200 metres. Its productive capacity has been estimated to be 5,000 to 10,000 barrels of oil per day.

An independent assessment of geological and well data by DeGolyer and MacNaughton, a Dallas consulting firm, indicates that the Kopanoar structure contains from 270 million to 1.8 billion barrels of recoverable oil.

(b) Koakoak

This structure is geologically similar to Kopanoar, and was tested by the 0-22 well in 1981. Oil was produced from a depth of 3,475 m at a rate of 2,830 barrels per day. Rock core samples from this well have excellent reservoir characteristics which indicate the potential for good well productivities. This well's productive capacity has been estimated to be a minimum of 5,000 barrels of oil per day from the partially tested hydrocarbon zone.

The geological and well data was analyzed by DeGolyer and MacNaughton who determined that the recoverable reserves for the Koakoak structure could range from 300 million to 2.0 billion barrels of oil.

(c) Tarsiut

The Tarsiut structure was first drilled and tested in 1980 by the A-25 well which produced oil at 800 barrels per day from a depth of 1,500 metres. Subsequent seismic and geological analysis of this structure indicated that the sands thicken and improve in quality to the east so a second well is presently being drilled three kilometres east of A-25. This well (N-44) is being drilled from an artificial island, has penetrated the oil zone tested by the A-25 well, and is being drilled deeper to evaluate potential oil zones to a depth of 5,000 metres.

Although an independent assessment of the Tarsiut structure recoverable reserves has yet to be done, it is worth noting that the area of the Tarsiut structure is larger than either Kopanoar and Koakoak, and hence has the potential for larger reserves.

(d) Nektoralik

The Nektoralik K-59 well was Dome's first oil discovery in the Beaufort. It produced oil at 380 barrels per day from a depth of 2,700 metres. It is also classified as a gas discovery, since gas was produced at a rate of 5 million cubic feet per day from a depth of 2,260 metres.

The geological interpretation of the reservoir indicates that the well was drilled on top of an anticlinal structure where the sands are thinnest. To verify the thickening of the sands on the flanks of such structures a well is being drilled on the adjacent Orvilruk structure, which is geologically similar.

(e) Ukalerk

Ukalerk is a gas reservoir, discovered in 1977 by the C-50 well. It produced gas at 17 million cubic feet per day and has an absolute open flow potential of 200 million cubic feet per day. Mechanical problems forced abandonment of the well, and a confirmation well was then drilled. The 2C-50 well flowed gas at 3 million cubic feet per day and has an absolute open flow potential of 85 million cubic feet per day.

The Ukalerk structure has a potential hydrocarbon capacity of 3.9 to 6.6 trillion cubic feet of gas.

(f) Abandoned Wells

The Tingmiark K-91 well, drilled in 1976, had to be abandoned before testing could be conducted, when mechanical problems prevented further drilling. An indication of gas had occurred in the well, suggesting that it may be a gas discovery since it is geologically similar to Ukalerk.

The Kilannak A-77 is the only well drilled by Dome in the Beaufort in which no significant amounts of hydrocarbons were discovered. Abandoned in 1981, this well was drilled in a completely different geological environment than that of all the other Beaufort wells, so its abandonment does not reflect negatively on the rest of the Beaufort basin.

(g) Suspended Wells

Wells which are currently suspended and awaiting further operations are Orvilruk 0-3 (discussed earlier), Kenalooak J-94, Irkaluk B-35, Natsek E-56 and Nerlerk M-98.

Kenalooak and Irkaluk were drilled in the 1979/1980 seasons and 1981 season, respectively, and are structures in the general Kopanoar and Koakoak trend. Additional drilling needs to be completed before these wells are tested.

Natsek and Nerlerk were both drilled to total depth in 1979. Natsek had some hydrocarbon indications but has not yet been tested. Nerlerk had some significant oil indications but was only partially tested. Testing of additional zones will be carried out as drillship schedules permit.

## 2.5 RESERVES

In 1976 the Department of Energy, Mines and Resources placed the oil reserve potential of the Beaufort Sea region at 6.9 billion barrels and gas reserves at 60 trillion cubic feet (TCF), at a 50% level of confidence. Proven oil reserves in the Mackenzie Delta are about 400 million barrels, and proven gas reserves are in the order of 6 TCF. Industry estimates that there are up to 90 seismic anomalies in the offshore area, of which approximately one quarter may be capable of commercial production. Dome has identified more than 40 potential hydrocarbon bearing geological structures in its lease area (Figure 2.5.1) alone.

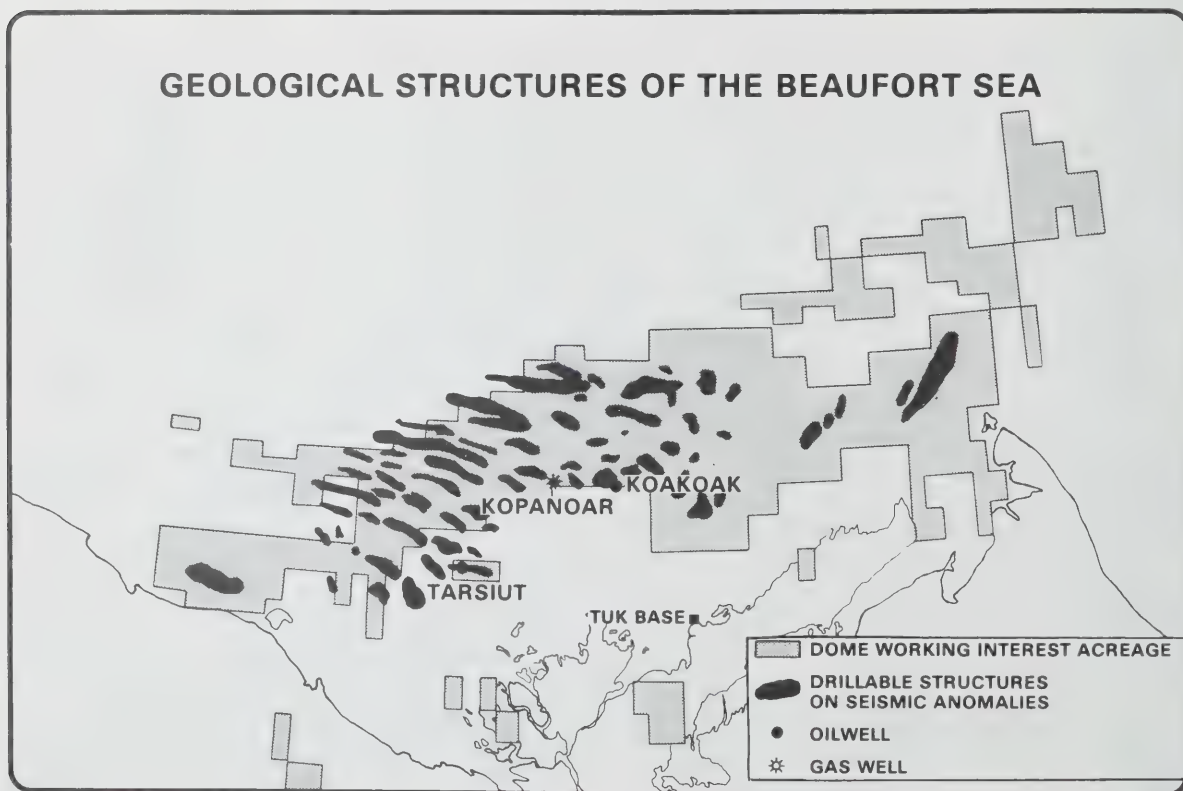
Based on results to date, Dome has a 50% level of confidence that the ultimate oil potential of the Beaufort is about 32 billion barrels. The development of these frontier reserves will make a major contribution towards fulfilling Canada's oil supply shortfall.

## 2.6 CRUDE OIL SUPPLY AND DEMAND

The recent National Energy Program (NEP), in conjunction with Government Bill C-48 and the Federal/Provincial Energy agreements, has confirmed the Federal Government's determination to pursue a policy of energy self-sufficiency for Canada. This policy is the most important

factor influencing this Country's future balance of oil supply and demand over the next two decades. Two recent exhaustive studies on Canada's energy supply and demand forecasts, the National Energy Boards' "Canadian Energy" study, and the Canadian Energy Research Institute study of 1981, provide the basic framework for this discussion. However, the forecasting of energy supply and demand is difficult, with many "uncertainties" such as economic growth, international price and productive capacity of oil sands and frontier resources. Because of these "uncertainties" it will be demonstrated that Canada should develop all new possible sources of crude oil including the oil sands, East Coast and the Beaufort Sea.

The demand forecasts in the National Energy Board (NEB) study are based on a combination of population growth (averaging 1 percent per annum), economic growth (averaging 3.2 percent per annum) and energy price assumptions for the next two decades. Based on these assumptions, which equate to a yearly growth of 2.3 percent for the next 20 years, Canadian primary energy demand was forecast to be equivalent to 7.2 million barrels of oil daily (BOPD) in the year 2000 compared to 4.6 million BOPD in 1980. However, the NEB forecasted a decline in the demand for crude oil representing only 26 percent of the total energy demand by the year 2000, compared with 39 percent in 1980. It adopted a range of models or case studies to handle the "uncertainties" in forecasting oil supply and demand using four supply and three demand possibilities. Figure



**FIGURE 2.5.1** Potential hydrocarbon bearing, or drillable structures in Dome interest lands. Over 40 such structures have been identified.

2.6.1 illustrate the total range between the low supply and high demand forecasts, representing a supply shortfall of some 1.8 million BOPD by the year 2000.

Figure 2.6.2 represents Dome's current view on the supply of and demand for oil in Canada. The demand curve is based on the NEB "Moderate Demand," which shows a decline from 1.8 million BOPD in 1981 to 1.7 million BOPD in 1990, but then growing to 1.9 million BOPD by the year 2000, resulting in an average overall demand growth of oil of 0.2 percent per annum or a total increase in consumption of 5 percent.

Although this growth rate is small, established conventional crude oil reserves are only estimated at 4-6 billion barrels, which at present production rates, will only last about 10 years. The NEB forecast that the productive capacity from conventional sources will decline from 1.45 million BOPD in 1980 to 315,000 BOPD by 1995. However, they project that by 1995 new discoveries in conventional producing regions, plus new supplies through enhanced recovery techniques in those established regions, will provide 390,000 BOPD of additional supplies, thereby improving the total supply to 700,000 BOPD. Existing oil sands plants contribute an additional 140,000 BOPD of supply. This represents the NEB "Base Supply" in Figure 2.6.2.

The shortfall in supply using these two curves is then 600,000 BOPD in 1985, climbing to 700,000 by 1990 and 1.2 million by 2000. This shortfall is enormous and must be met by the construction of oil sands plants and the development of frontier resources if "self-sufficiency" is to be achieved. The NEB in its high supply case projected this shortfall would be made up mostly by oil sands production (up to six new plants and one major expansion at a cost of \$90 to 120 billion) and oil from frontier regions at a rate of 400,000 BOPD by 2000.

Dome believes that this program of oil sands construction is improbable and at the enormous cost, doubtful economics, and long construction period (8 years), only two new plants will be producing by 1995. Therefore additional oil sands production by 1990 will be in the order of 150,000 BOPD rising to 350,000 by the year 2000, including expansion at the present Syncrude plant. The East Coast should certainly be producing by 1990 at a rate of 200,000 BOPD rising to close to 300,000 BOPD by 2000.

The shortfall will still be 350,000 BOPD in 1990, rising to 600,000 BOPD by the year 2000. Dome believes that the Beaufort Sea has the potential to meet this demand and considerably more if required. Therefore, an all out effort should be encouraged to delineate and prove the productivity of the Beaufort Sea.

As discussed earlier the time to bring oil sands and the East Coast into full production is 6 to 8 years away. However an early production scheme, which would prove the produc-

tivity of the Beaufort Sea, could be on production in three to four years, and it could significantly help to arrest the dramatic decline in supply anticipated from conventional sources.

The Canadian Energy Research Institute (CERI) study reaches very similar conclusions to those of the NEB. It deals with the Canadian oil supply and demand outlook in a probabilistic manner using a low, base and high set of supply and demand assumptions, taking into account oil sources, quality and transportation parameters. Conventional light and medium crude oil are forecast to decline in relative importance — from 70 percent of the domestic supply in 1985 down to only 25 percent in the year 2000. Synthetic and frontier oils are predicted to increase from 14 percent of the domestic supply in 1985 up to between 50 and 60 percent by the year 2000.

The study came to the following additional conclusions:

- the expected quantity of oil imports will peak at 500,000 BOPD or 28 percent of domestic demand in 1985. If the various oil sands and frontier sources of oil are developed, this import dependency will decline to the year 2000 to a point where Canada may have a modest exportable surplus of 40,000 BOPD.
- most of the supplemental supplies of oil will be required in Quebec and the Atlantic provinces. That supplemental need is estimated to be 1.2 million barrels a day in 1990 and 1.5 million barrels a day by the year 2000, assuming the base case is applied.
- Allowing for tertiary recovery sources from well established oil fields, and new supplies from those fields in western Canada, a shortfall of 500,000 BOPD in 1990 and 1.0 million BOPD in 2000 are predicted. This will have to be met by imports, new oil sands plants, or frontier region oil.

## Conclusions

Both the NEB inquiry report and the CERI study identify a substantial need for additional oil supplies even in the most optimistic oil demand scenario.

Considering the uncertainties surrounding the development of oil sands plants, their doubtful economics and long construction periods, frontier oil will have to be developed if Canada is to reach her self-sufficiency goals. It is unlikely that the East Coast can meet the full frontier oil requirements. The Beaufort Sea has significant potential for economic oil production, and the ability to construct small scale schemes at an early date.

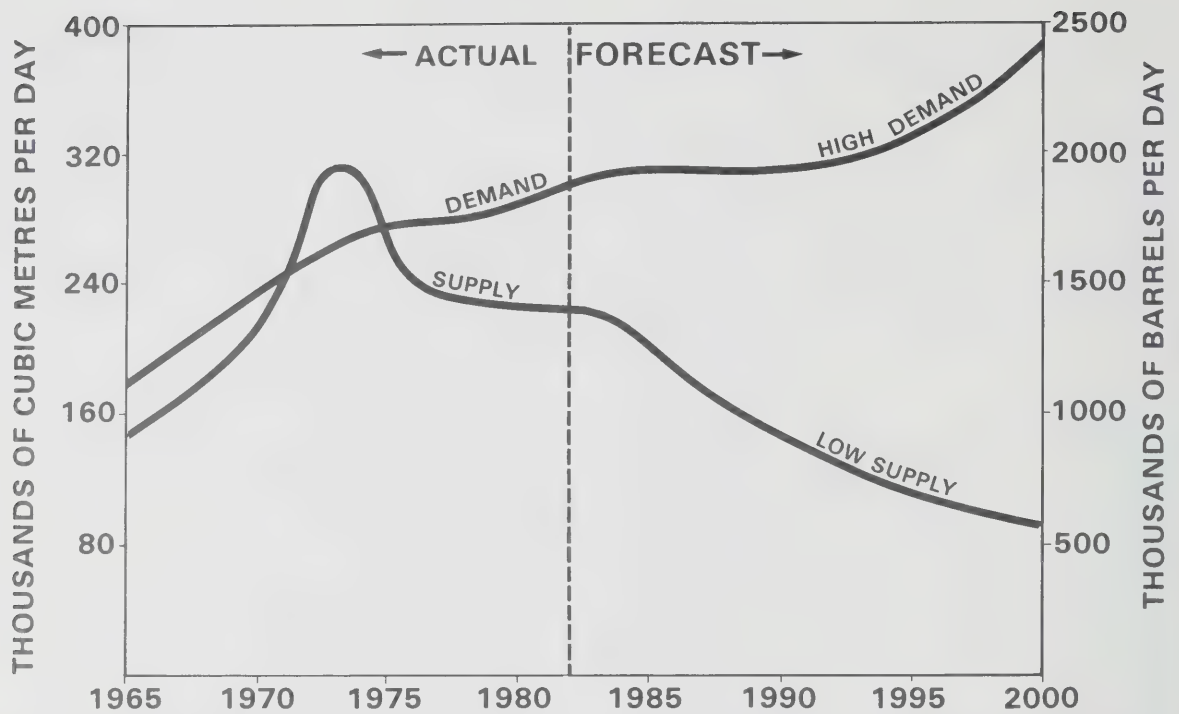


FIGURE 2.6.1 National Energy Board Forecast (1981) showing the total range of supply shortfall between low supply and high demand.

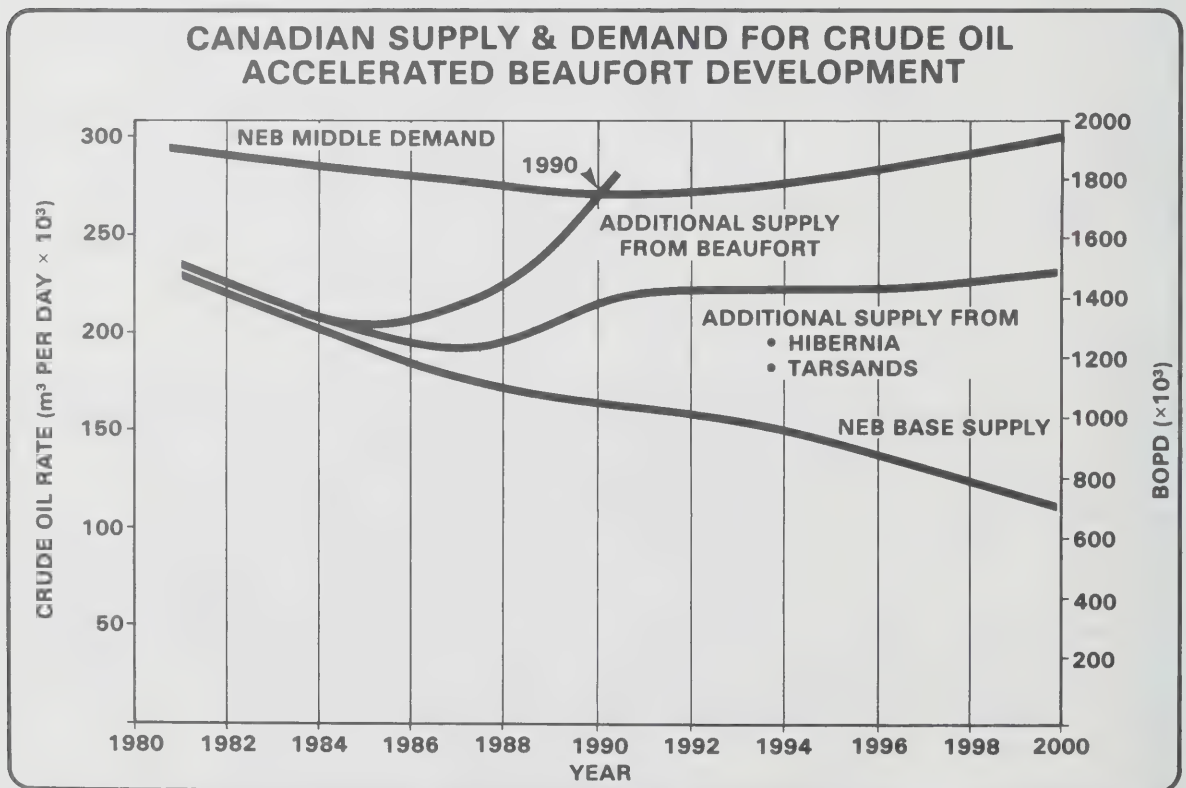


FIGURE 2.6.2 Dome's view of the oil supply and demand picture and how additional supplies from Tarsands, Hibernia, and the Beaufort can meet projected demand. In particular, note that Beaufort can meet the supply shortfall earlier than the other options, between 1985 and 1990.

## **SUMMARY OF SECTION 3.0**

### **FUTURE DEVELOPMENT**

3.1 Because of projected oil shortfalls, and the need to secure new sources of Canadian oil, production from the Beaufort and all potential domestic sources should be initiated as soon as possible.

3.2 Current Beaufort delineation drilling plans should establish the commercial viability of potential oil fields at Tarsiut by the end of 1982, Koakoak by the end of 1984 and Kopanoar in 1985.

3.3 Subject to drilling results and regulatory approvals, development of the Tarsiut field could commence during 1983, with limited early production being achieved by 1985. The initial oil would be transported to market by icebreaking tanker.

3.4 Once initial production is achieved, the pace of subsequent development, and therefore production, should be regulated to suit Canada's needs.

3.5 Achieving initial oil production by 1985 would be a considerable accomplishment and would contribute significantly to the controlled, incremental development of the Beaufort reserves.

3.6 Although both pipelines and tankers are considered to be feasible transportation systems, only through the use of tankers can the Beaufort Sea make an early contribution to Canada's oil supply position. Furthermore pipelines do not become practical until oil throughput rates exceed 350,000 BOPD, representing a 36" diameter pipeline. Until then, the advantages of tankers, in terms of many factors including flexibility, incrementability, cost economics, and industrial and social development strategies weigh significantly in favour of their use to transport Beaufort oil.



### 3.0 FUTURE DEVELOPMENT

This section of the submission serves to examine the development objective, and in response to this objective the company's 1982 drilling plans, the proposed development schedule for Beaufort Sea production, and the options under consideration for transporting oil to market.

### 3.1 THE DEVELOPMENT OBJECTIVE

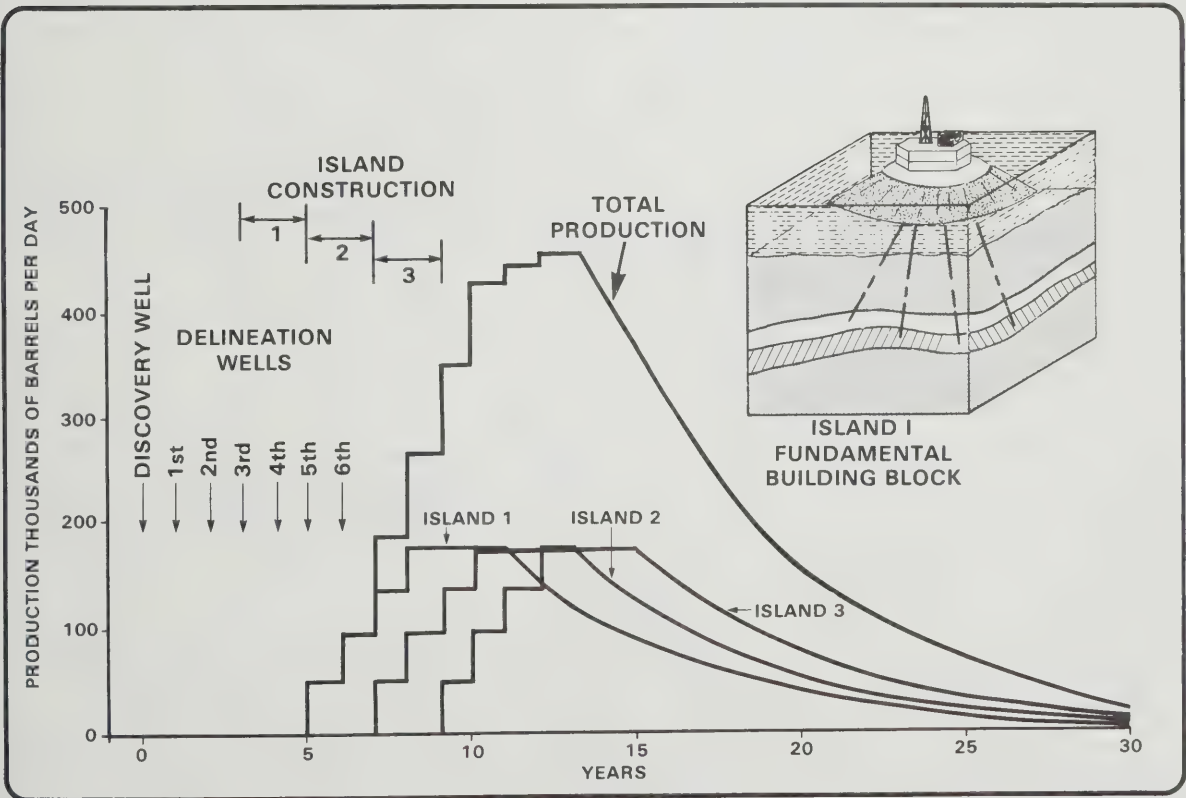
The Beaufort Sea-Mackenzie Delta region has the potential to help Canada become self-sufficient in oil production within this decade and in the process could stimulate considerable economic and employment activity in Canada.

The objective of commencing oil production from the Beaufort Sea is consistent with the national interests and goals of all Canadians; oil self-sufficiency by 1990, regional benefits where possible and increased technological infrastructure to ensure employment opportunities. However, the total potential of the Beaufort Sea-Mackenzie Delta region for oil and Canadian benefits cannot be realized unless production is allowed to begin. Basic building blocks must be put in place now to achieve results in the future.

Recognizing the difficulty of forecasting demand, and long lead times to develop the supply alternatives, and the potential of a sudden interruption in foreign supplies, the only prudent direction that the country can follow at this juncture is development of all of the alternative energy sources. Once production has commenced from the East Coast and from the Arctic the government will be in a much better position to match supply and demand by controlling the pace of further development in these areas.

The time frame then for Beaufort production is to commence as early as possible. The pace of development thereafter can be controlled to be compatible with other government interests. The basic building block for any oil production development is the production performance of each reservoir that is discovered. The rate that these reservoirs are discovered and brought on production is the development plan. The constraints to development will determine the actual overall production rate from the Beaufort Sea-Mackenzie Delta region and the ultimate effect of frontier oil on Canadian need.

Figure 3.1.1 is the forecasted production profile for a field like Tarsiut, Koakoak or Kopanoar. The production increases in a step-wise fashion as wells are drilled from an artificial island and placed on production. Note that this requires production and drilling operations to be taking



**FIGURE 3.1.1** Typical production profile for a new field in the offshore Beaufort. Production increases in a stepwise fashion depending on the number of islands built, and wells drilled.

place simultaneously. Peak production rate is reached after all the wells have been drilled. This rate is maintained for several years and then it commences decline as the reservoir energy is depleted. It is important to note that this production profile is based on the reserves accessible from a development island location and not from the total field. This is a reasonable treatment since the area accessible from a single island will be large - approximately 4 miles in diameter.

The shape of the production profile is determined by the reservoir characteristics, the producability of the wells, reservoir management and field economics. It is however, usually desirable to achieve the peak production rate within three or four years of placing a field on production and maintaining this peak production for a four or five year period.

Further reservoirs are systematically discovered and placed on production in the most technically efficient manner to achieve a continuing oil supply. A range of production profiles each representing its own development plan is shown in Figure 3.1.2. Displaying a range of achievable production rates is the only practical way to discuss Beaufort production, recognizing the large number of variables - technical, environmental, economic and regulatory, that impact on development. The Beaufort production profiles represent an addition of the production profiles of all of the reservoirs that are brought on production in the Beaufort over the forecast period.

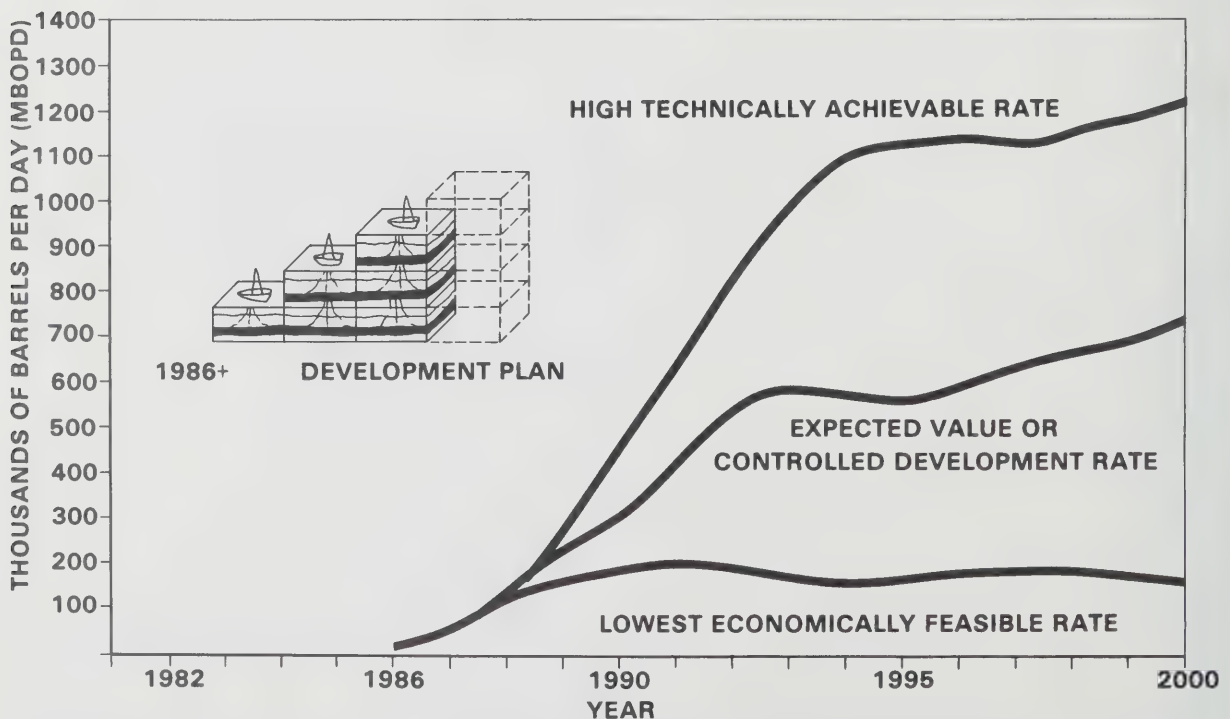
The high case is a technically achievable case and in the opinion of the proponents has acceptable environmental and socio-economic impacts. One could display an even higher case if a national emergency justified a higher level of activity.

The low case is based on lower oil reserve assumptions and a slower pace of development. The slower pace of development would be caused by government decree, severe environmental conditions, or operational problems.

A complete array of production profiles exist between the low case and the high case, one of which will be the likely production case or Expected Value Production Rate on Figure 3.1.2. A computerized model which relates all of the variables and assumptions has been developed. The model enables one to quickly determine the sensitivity of the variables which affect environmental and socio-economic impact to changing assumptions.

It should be noted that the general character of the production profiles is unchanged for the marine or pipeline transportation scenarios. The pipeline transportation alternative tends to shift the curves to the right, that is, a later start date for production because the threshold reserve is higher for a pipeline system than for a marine system.

Major project planning has become a sophisticated science. Large projects dictate the need to take into account thousands of events and factors that interrelate to bring the



**FIGURE 3.1.2** A range of production rates can be achieved depending on the need for oil and the numerous other variables which will influence development. The likely production rate will probably fall between the highest, technically achievable rate, and the lowest economically feasible rate.

project to a conclusion - be it first oil production or continued oil production. Computers have provided the capability to assess the large amounts of data available and the interrelationships between variables. This type of detailed planning is always preceded with the development of detailed lists of project planning constraints and assumptions. As more data become available the designers, with the help of the computer, can test the validity of assumptions and narrow their conceptual designs to a few workable concepts. The final selection of a design is usually based on economics, operational practicality, technical feasibility and environmental and social concerns. This process is ongoing, however, the array of development plans presented here are thought to represent the best presently available conceptual designs and to include the development ultimately pursued.

To assess the feasibility of producing oil from the region the reservoir reserve size is the most significant variable. In simple terms the oil reservoirs must contain sufficient recoverable oil to make development, production, and transportation of oil economic. The exploration program is focused on locating and delineating these type of reservoirs.

Table 3.1.1 is a listing of reserves that have been assumed for the first four reservoirs likely to be produced. The table also lists the discovery date, when delineation wells are drilled, when islands are completed and when first production occurs.

opment scheme will be used. Commitments are made to proceed with an island after the discovery well and two delineation wells have been drilled. Production from each island commences one year after the island has been completed.

Well producibility is an important field characteristic (but not as significant as reserves). Well producibility determines the number of wells that must be drilled in order to deplete full reserves in a reasonable period of time.

Other pertinent assumptions follow:

1. One injection well drilled per two producing wells drilled.
2. Reserves are recovered in the 25 year life for an island.
3. Deep horizon production islands use 3 rigs per island.
4. Shallow horizon production islands use 1 rig per island.
5. Each deep production rig drills 3 wells per year.
6. Each shallow production rig drills 8 wells per year for shallow horizons and 6 wells per year for medium horizons.

**TABLE 3.1.1**  
**BASIC RESERVOIR ASSUMPTIONS**

FIELD	DISCOVERY DATE	ISLANDS REQUIRED & COMPLETION DATE	ASSUMED RECOVERABLE (MILLION BARRELS)		DATE WELLS DRILLED	FIRST PRODUCTION DATE
			PER ISLAND	PER FIELD		
#1 SHALLOW	1979	1 (84)	125		2 in 82	85
		2 (85)	125		2 in 83	86
		3 (86)	125	625	1 in 83 & 84	87
		4 (87)	125		2 in 84	88
		5 (88)	125		2 in 85	89
#2 DEEP	1981	1 (86)	600		1 in 83, 84	87
		2 (88)	600	1800	1 in 85, 86	89
		3 (90)	600		1 in 87, 88	91
#3 SHALLOW	1981	1 (87)	200	400	1 in 83, 84	88
		2 (88)	200		1 in 84, 85	89
#4 DEEP	1979	1 (87)	600	1200	1 in 81, 83	88
		2 (89)	600		1 in 84, 85	90

It should be noted that discovery dates go back to 1979. Offshore discoveries by industry to date include Nektoralik, Kopanoar, Tarsiut, Koakoak, and Issungnak. The success of delineation drilling will determine which discoveries are developed first. It is assumed that an island devel-

7. Injection commences 2 years after production at all deep islands, and all shallow fields except one where injection commences 1 year after oil production.
8. 3 to 5 year peak production period per island.

9. 15 to 20% required annual production decline range.
10. Peak field production to reserve ratio (R/P) is equal to 10.

The production profile that results from a typical field was shown earlier in Figure 3.1.1.

The reserve size, production rates and other reservoir data are consistent with the best information available from Beaufort discoveries.

The exploration schedule is generally driven by the assumed pace of development. It is further assumed that one commercial discovery results from each ten wildcat exploration wells that are drilled. Thus, one can work backwards from the assumed discovery dates and development dates to determine the schedule for exploration and development wells.

As stated earlier, a commercial discovery, by definition, requires a large enough oil accumulation to justify the investment required to develop the find, place it on production, transport it, and operate it profitably for the life of the field. The threshold reserve is that level of reserves which will be sufficient to enable the developer to proceed with the investments required for development. In conventional onshore operations in the south, threshold reserves are very low. In remote or more difficult areas like the Beaufort or the North Sea they are high. In the case of the Beaufort offshore, threshold reserves are expected to range from 300 to 700 million barrels assuming tanker transportation and 2.5 billion barrels assuming pipeline transportation.

The transportation system that will be used for carrying Beaufort oil to the south may be a significant factor affecting threshold reserves. A pipeline system requires a new pipeline approximately 1,400 miles long. This system will cost at least \$12 billion. Sufficient oil reserves must be in hand to justify this pipeline plus the cost of the islands, wells and other producing facilities before any development would commence. After a pipeline was in place new fields would be brought on production if they could pay out their development costs alone (providing there was space in the pipeline). In the case of tankers the threshold reserve for the first development is lower simply because the cost of one or two tankers (each tanker will handle about 50,000 bpd) is much less than the cost of a pipeline. After the first system is in place, additional discoveries are brought on production if the cost of development plus additional tankers can be justified.

There are two principal regulatory approval processes that the proponents must pursue relative to production from the Beaufort Sea-Mackenzie Delta Region. These are the Environmental Assessment Review Process (EARP), and Approval of the Plan of Development by the Department of Indian Affairs and Northern Development (DIAND).

The EARP can be considered to provide environmental and socio-economic clearance for the project. Plan of Development approval provides engineering clearance for the project.

There will be a number of other regulatory approvals or permits required for specific components of the project, such as ocean dumping permits, land use permits, marine vessel certification, shipping and receiving terminals approvals and drilling licenses.

The proponents must receive the principal project regulatory approval prior to making major financial commitments. These major financial commitments begin about 3 years before first production or in late 1983. This then provides a 2 year period from the present time for the approvals process.

Both the regulatory approvals schedule and the construction schedule must be maintained if first oil is to be produced by 1986.

## 3.2 1982 DRILLING PLAN

Dome intends to undertake an aggressive drilling and evaluation program in the Beaufort Sea during 1982. All four Canmar drillships will be operating in the Beaufort under contract to Dome to conduct the exploration program.

The company currently proposes to complete three wells that were suspended at the end of 1981, and to drill and test up to four additional wells during the 1982 drilling season. We intend to re-enter and complete the Irkaluk B-35 well, the Kenalooak J-94, and the Orvilruk O-03 well. As well as completing the above wells, if time and conditions permit, we propose to drill and test up to three wells at Tarsiut and to spud two more at Siulik and Arluk.

Dome's 1982 drilling schedule projects a total of 15,600 m drilled, approximately 2.25 times that drilled in 1981 and approximately 1.2 times the amount drilled in 1980. The proposed 1982 exploration and appraisal drilling schedule is illustrated in Figure 3.2.1.

In addition, drilling is presently underway at the Tarsiut artificial island, with testing scheduled for completion by late spring 1982. This well is being drilled much deeper than the shallow discovery zone to test deeper horizons. Findings in the deep zones will affect the timing and drilling of additional delineation wells, but assuming the initial findings are positive, two more wells could be drilled and tested from the island and up to three more from drillships before the end of 1982.

PROPOSED 1982 EXPLORATION AND APPRAISAL DRILLING PROGRAM

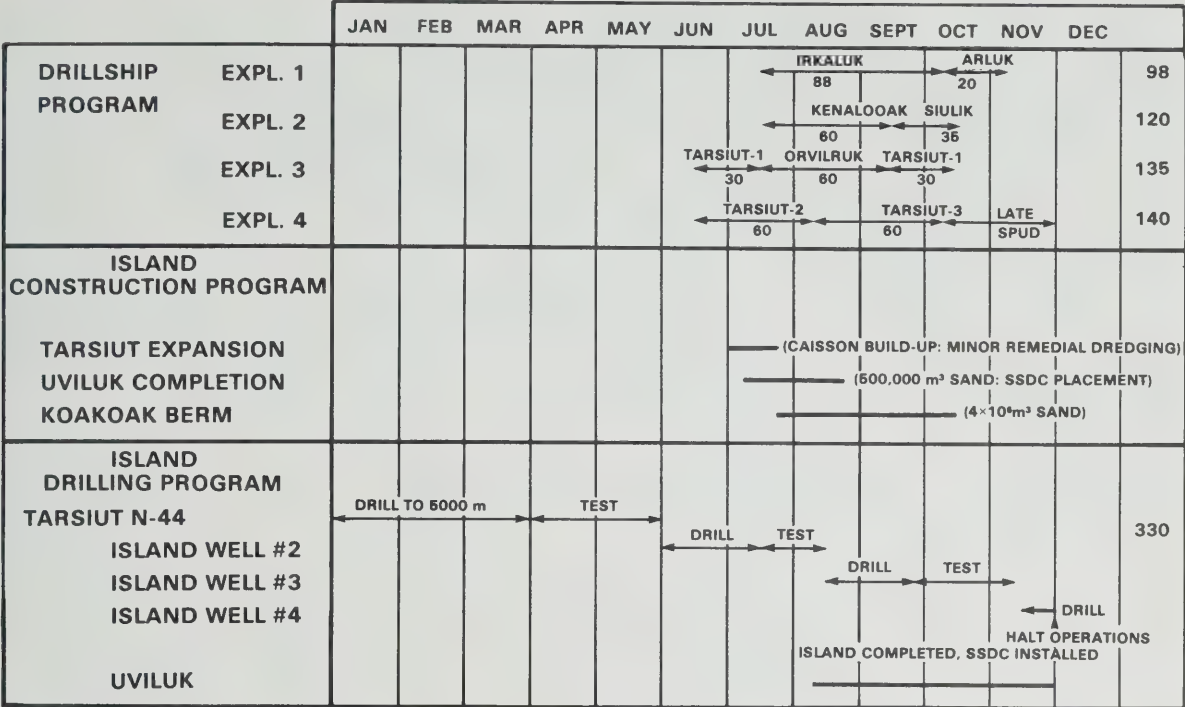


FIGURE 3.2.1 The proposed 1982 exploration and appraisal drilling program.

3.3 DEVELOPMENT SCHEDULE

The development schedule leading to future production from the Beaufort Sea is dependent on numerous factors. They include: the time taken to delineate a discovery; water depths and location of the field; the transportation mode employed, particularly in the early stages of development; the complexity of the production scheme selected; and government approvals.

Shallow water developments (less than 25 m) will be simpler to bring on production than deep water developments (30-60 m). This is because much less dredged material will be required to build the necessary islands, and the islands themselves can be designed for lower levels of ice forces, since most of the larger ice features will be prevented from moving into this area due to draught considerations. Likewise, finding the oil in shallow zones (less than 2,000 m) will make such fields easier to develop than those with deeper reservoirs because the well pressures will be lower and drilling time will be reduced. For this presentation, we will examine in detail the present plan for developing the Tarsiut field. This will be followed by a very brief review of proposed plans for other likely fields at Koakoak and Kopanoar. Figure 3.3.1 summarized our present overall development plan for the Beaufort region.

(a) Tarsiut Development

The Tarsiut discovery holds great promise for early pro-

duction from the Beaufort because the water is relatively shallow, ranging from 17 - 22 metres deep, and the discovery zone is at roughly 1,500 metres. Furthermore, the Tarsiut structure (like most structures in the Beaufort) is simple so only a few delineation wells will be required around each prospective island location to justify proceeding with development. As an example, Prudhoe Bay, 500 miles to the west, was evaluated with only 2 wells. This structure, illustrated in Figure 3.3.2, is approximately 20 miles long, by two miles wide. It indicates the potential ultimate development scheme with five development islands including one Artificial Production and Loading Atoll (APLA). The present island could be modified to accommodate an early production scheme (Section 3.5). Also shown are the discovery well, the first delineation well, which is presently being drilled, and the possible site(s) for additional delineation wells.

(i) Delineation Drilling

As discussed previously, the first delineation well is presently being drilled and will be tested by late spring 1982. At least two further delineation wells could be drilled and tested from the island and up to three drilled and tested from drillships by the end of 1982. Based on success, the company should be in a position to propose major commitments leading to development of the field at this time.

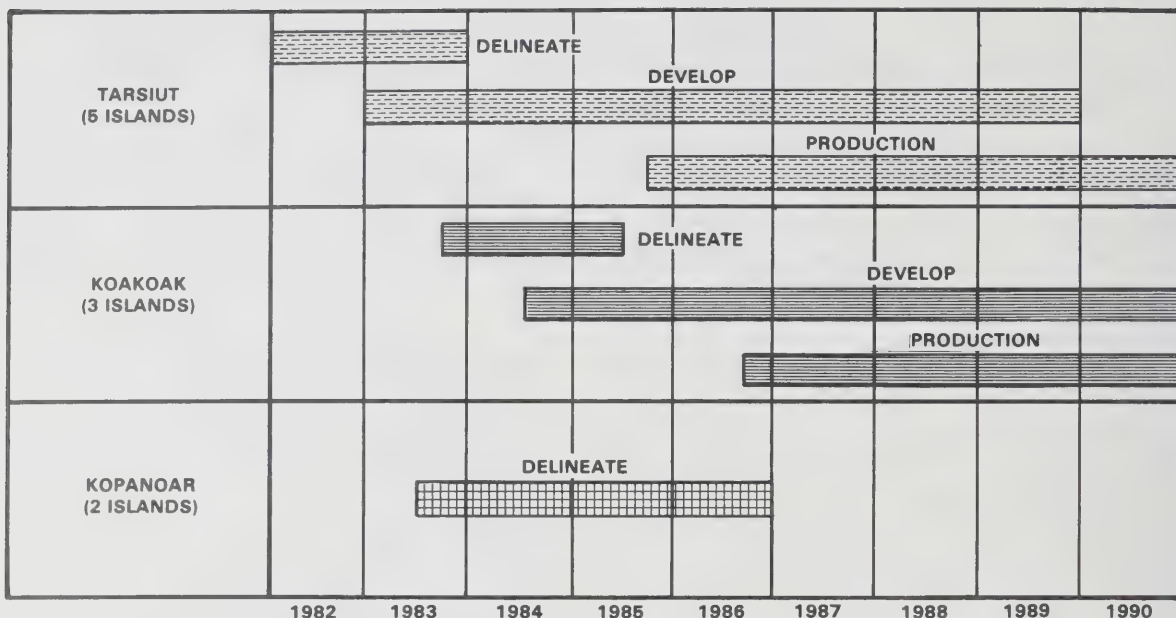


FIGURE 3.3.1 Dome's projected Beaufort Sea Overall Development Plans for the first 3 Fields.

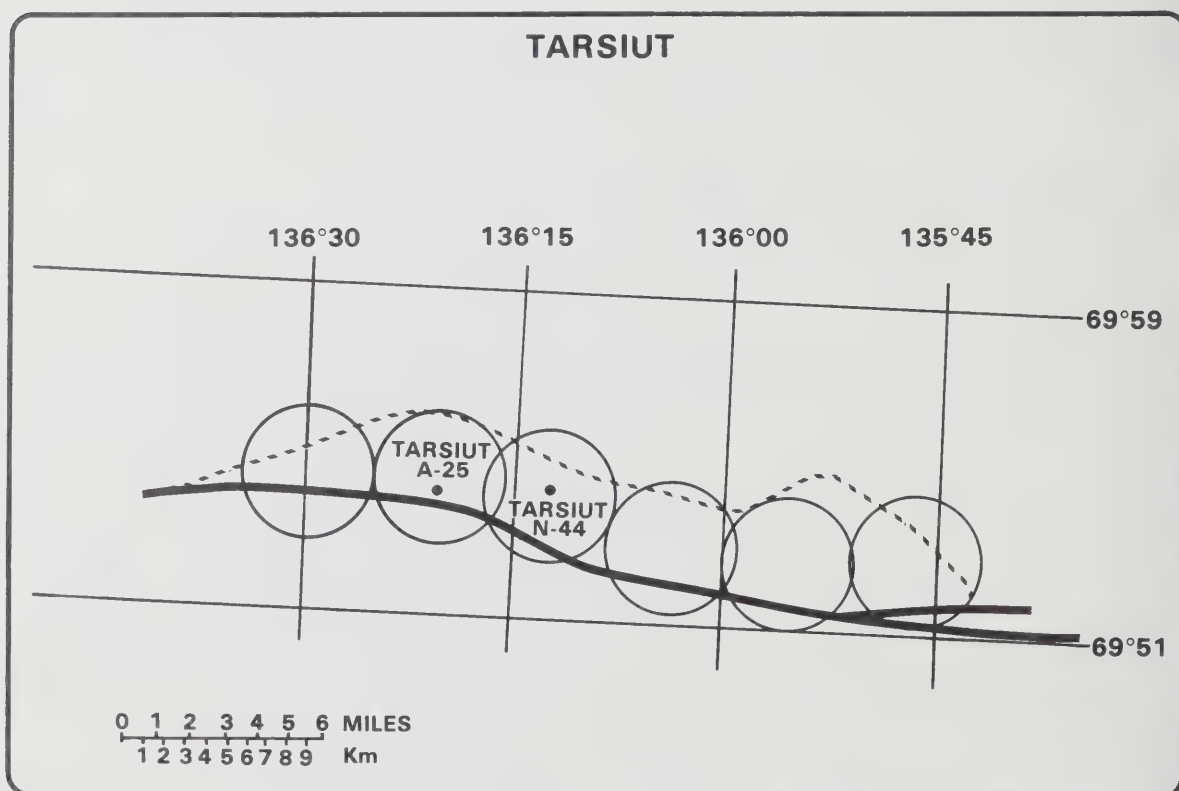


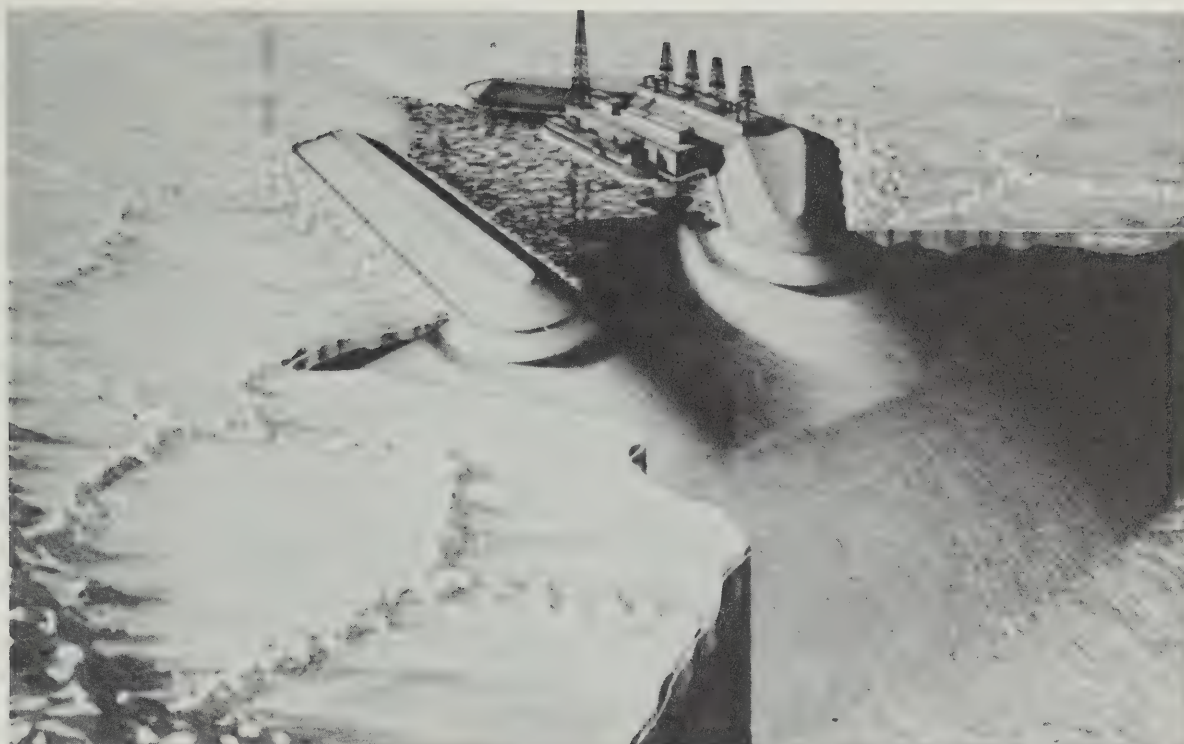
FIGURE 3.2.2. The structure map for the Tarsiut field. The structure is 20 miles long by 2 miles wide and would require up to 5 development islands to efficiently produce the recoverable oil.

#### (ii) Prototype Island Construction and Evaluation

The exploration island completed in 1981, has been designed as a prototype for future production structures. The performance of this island will be monitored through

the winters of 81/82 and 82/83 to determine the magnitude of the ice forces and the effectiveness of the design features. These data will be used to optimize the design of future artificial island structures.

#### (iii) Island Construction



**PLATE 3.3.1** *The Arctic Production and Loading Atoll (APLA) is a proposed crude oil storage and marine terminal for loading icebreaker tankers which would carry crude oil to markets. In the event the atoll was suitably located over a hydrocarbon reservoir, it could also function as a production platform. This artist's rendering was one of the earlier versions.*

The volume of material required for the series of artificial islands and the APLA is approximately 36 million cubic metres. The basic development islands will be constructed using conventional equipment at a rate of one per year. Conversion of the present exploration island into an APLA will take approximately 2 years with construction beginning in 1983. The design parameters of the production islands and the APLA will be governed by the process and drilling space requirements and the results of the island monitoring program.

#### (iv) Production Facilities

The early production scheme which could be on line by 1985 will be discussed further in Section 3.5. The following describes the sequencing of the main production facilities. The preliminary designs undertaken in 1981 will be refined into detailed designs during 1983, after assessing the results of the first three delineation wells.

Approximately 2.5 years have been allowed for the fabrication and precommissioning of the first main unit. It will probably be barge-mounted, constructed in southern Canada, then towed out to replace the early production system at the first production island (APLA) in the summer of 1986 for installation, hook-up and final commissioning. Subsequent units would be installed on completed islands at a rate of 1 per year until completion of the fifth island in 1991.

Due to the high degree of precommissioning undertaken before the production units leave the southern fabrication site, it is estimated that tow out and final commissioning would take six months. Fabrication of the production modules will take longer than is the case in the North Sea experience (20 months), but the commissioning phase will be generally shorter due to the greater degree of precommissioning referenced previously.

#### (v) Drilling Facilities

Approximately 1.5 years are required for the design and fabrication of the drilling packages. These, like the production modules, will be barge-mounted (two drilling rigs per barge) and towed to the completed islands. Production drilling will proceed from completed islands at the rate of six wells per rig per year, cumulating to 160 production and injection wells.

#### (vi) Storage and Loading Facilities

These facilities will be installed in the APLA. Design and construction is expected to take 2.5 years with tow out and commissioning planned for the summer of 1986.

#### (vii) Pipelines

Because of the shape of the Tarsiut field all production locations will be connected to the APLA by a subsea

pipeline. This will be carried out in phases with islands being connected when they become completed.

(viii) Arctic Tankers

Arctic tankers would be used to transport the crude oil produced to market. The number of tankers required to service this field would increase at a rate of one ship per 50,000 BOPD. Section 5.0 of this submission describes in detail the nature of the tankers presently being designed.

(ix) Capital Cost

The capital cost plus contingencies of the full field development (excluding tankers and an early production scheme) would approach \$7.3 billion (1982).

(b) Koakoak Development

This structure is approximately six miles in diameter and is located in water depths of 40 to 48 m. Development here represents the schedule for a medium-deep water field. Figure 3.3.3 is a structure map showing the discovery well, planned delineation wells and the development islands.

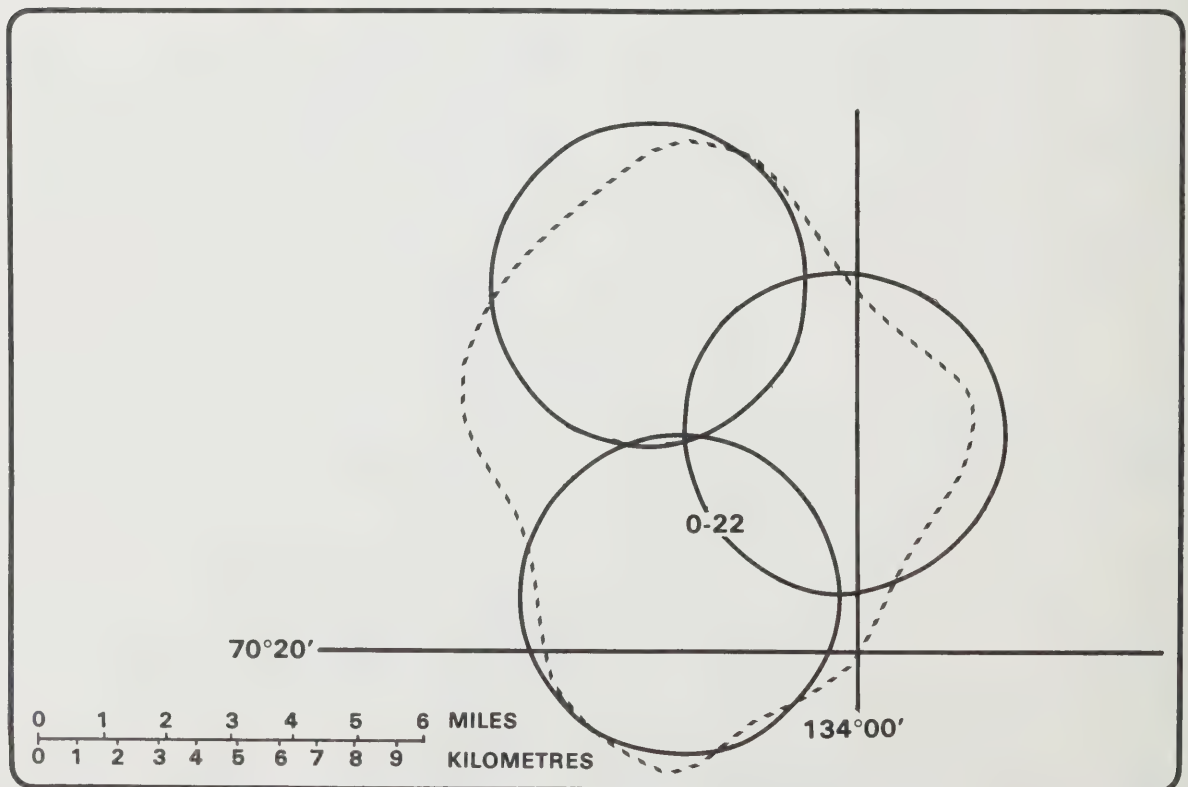
The full development of this reservoir will require three production islands and a shallow water (25 metres approx.) loading terminal. Should the Tarsiut development proceed with an APLA then the oil from Koakoak could be piped

to that location. If Tarsiut does not proceed, the storage and loading terminal will probably be located in the area near Issungnak.

An exploration island based on the Tarsiut design is proposed to be built at Koakoak during the 1982 and 83 open water seasons. This island will be constructed with conventional equipment, which is currently being modified to dredge in the deeper water of this area. Drilling will commence in late 1983, and, provided there are no restrictions on year-round drilling from this island, four additional delineation wells can be drilled and tested by the end of 1984. It is anticipated that these wells will provide sufficient information to determine the commercial viability of this field.

Subject to obtaining positive results and the necessary approvals, the exploration island will be enlarged beginning in 1984, with completion scheduled for 1988. Development will proceed in a similar manner to that at Tarsiut with the early production system being relocated to Koakoak in late 1986, and remaining at this field until 1988 when permanent facilities can be commissioned.

The two additional development islands will follow at a slower pace than Tarsiut because of the large material volumes required in the deeper water. The second island should be completed by 1991 and the third in 1993.



**FIGURE 3.3.3** The Koakoak structure located in 40 to 48 metres of water is approximately 6 miles (9 km) in diameter and would be developed using up to three island platforms.



**ARCTIC DREDGE**

**PLATE 3.3.2** *Dome is proposing to build large Arctic Class trailing suction hopper dredges referred to as Arctic Dredges to assist with island construction. The sand carrying capacity of the dredge will be 25,000 m<sup>3</sup>, roughly 2.5 times larger than existing equipment of this type.*

Arctic tankers would be used to transport the oil to market. The first one would be required in 1986, growing at the rate identified for Tarsiut, namely, one ship per 50,000 BOPD, to perhaps four by 1993.

#### (c) Kopanoar Development

Bringing Kopanoar into production represents a typical deep water field development. This was one of the first offshore discoveries in the Beaufort so much of the early production engineering was focused on this field. Later discoveries in shallower water have caused this field to be set back from original expectations. The Kopanoar structure is some 12 miles long by 3 miles wide, and is located in water depths of 60 to 65 metres. As illustrated in Figure 3.3.4, development of the reservoir will require two production centres; one on the East Lobe and the second on the West. As with Koakoak, to respect the earliest possible production date, an artificial island will be used to accommodate the production facilities. The storage and loading terminal will be at either Tarsiut, if that development has proceeded, or at some other shallow water (plus or minus 25 metres) location.

The Kopanoar 21-44 step-out well was drilled in 1981. A further three delineation wells will be drilled by the end of 1985. These wells will be drilled by drillships because the water depth is too great to permit construction of an

exploration island, with existing dredging equipment. It is anticipated that the results of the additional wells will give a sufficient level of confidence to proceed with the investments required for commercial development.

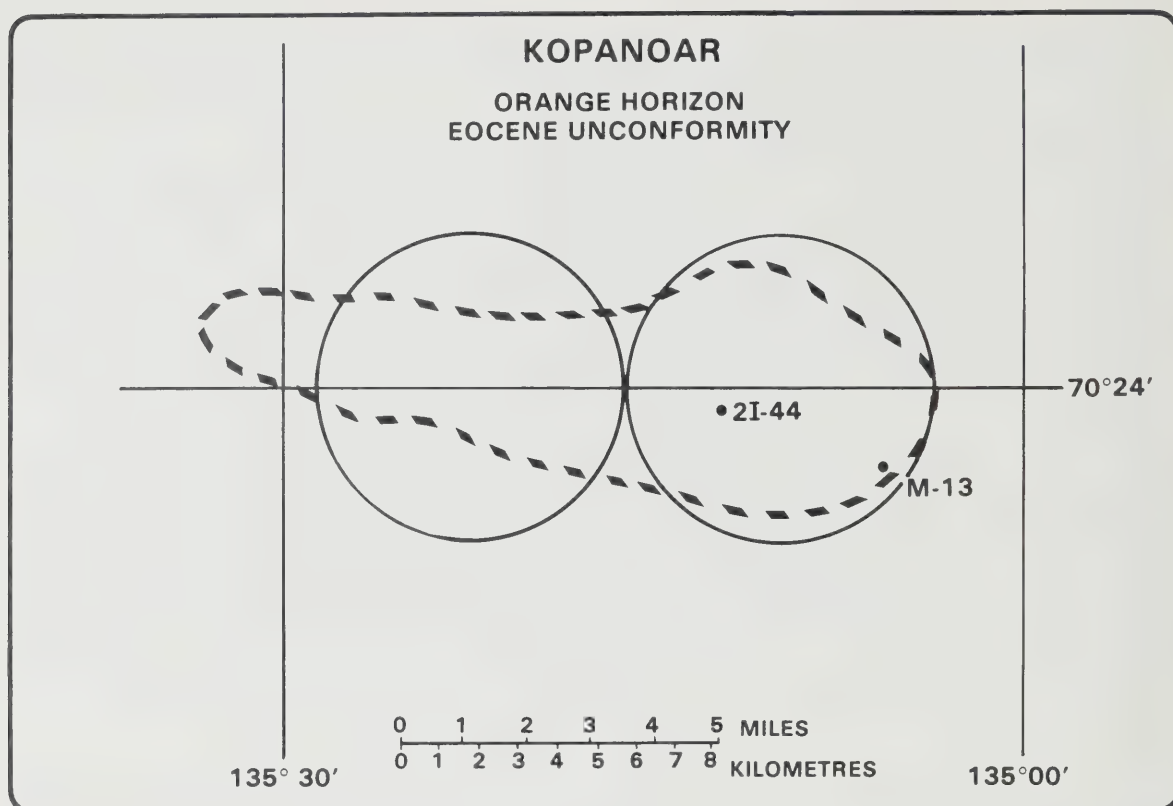
Because of the activities at Tarsiut and Koakoak the construction of the production islands would not be started until 1992 with commissioning of the first one in 1995 and the second in 1997.

Drilling rigs and production facilities similar to those employed at Tarsiut will be used at Kopanoar. Three drilling rigs will be placed on each island and production drilling will proceed at the rate of 3 wells per rig per year, reaching a total of 86 production and injection wells.

As with production from the previous two fields, oil would be transported to market with Arctic tankers. The first would be in service in 1995, with up to three additional units being needed when the field is in full production.

## 3.4 PACE OF DEVELOPMENT

The projected Beaufort Sea production profile discussed in Section 3.1 showed a range of possible production rates, with the principal variant being the pace of development. Assuming that Tarsiut, Koakoak and Kopanoar are all



**FIGURE 3.3.4** The Kopanoar structure is located in water depths of 60 to 65 metres. Development of this reservoir will likely require two island production centres.

commercial discoveries, there are a multitude of options, ranging from developing the fields one at a time over several years, to developing all three concurrently, as quickly as possible. The high production profile schedules the development so that there is never more than one island coming on production in any given year. Lower production scenarios provide considerably more time between development stages.

The pace of development dictates various factors, including the need for on site construction equipment, support services and personnel. Ideally, the development should not be spaced out so far as to require shut-down of the equipment between developments.

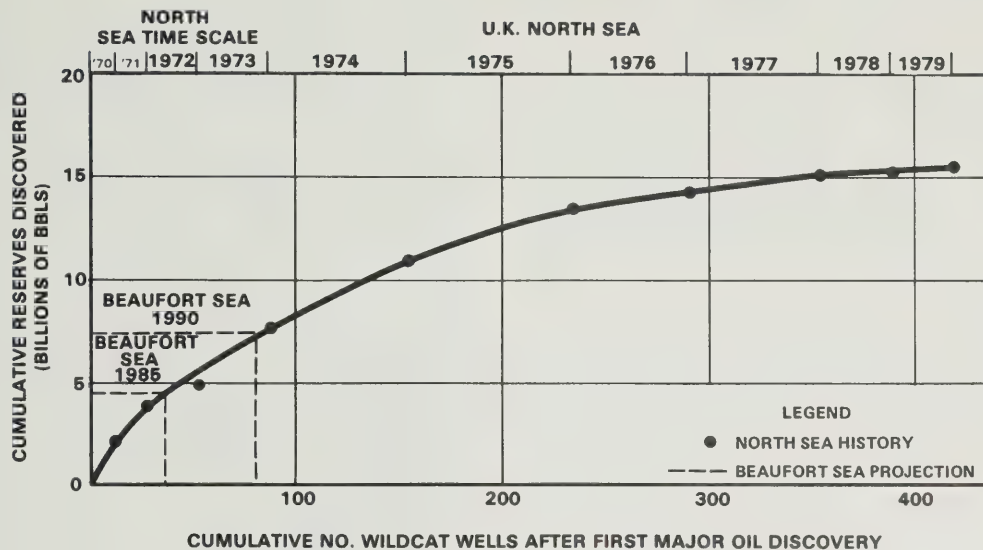
A technique for evaluating the reasonableness of projections is to compare them with actual experience in another similar area. The North Sea is similar to the Beaufort in the complexity of operations, and provides a worthwhile comparison.

Figure 3.4.1 is a graph which shows the cumulative discovered reserves in the U.K. North Sea, as a function of the number of wildcat exploration wells drilled after the discovery of the first major oilfield (Forties), in 1970. Figure 3.4.2 illustrates a projection of exploratory drilling activity by Dome and all operators in the Beaufort Sea over the next 10 years. It forecasts that some 36 wildcat wells will be

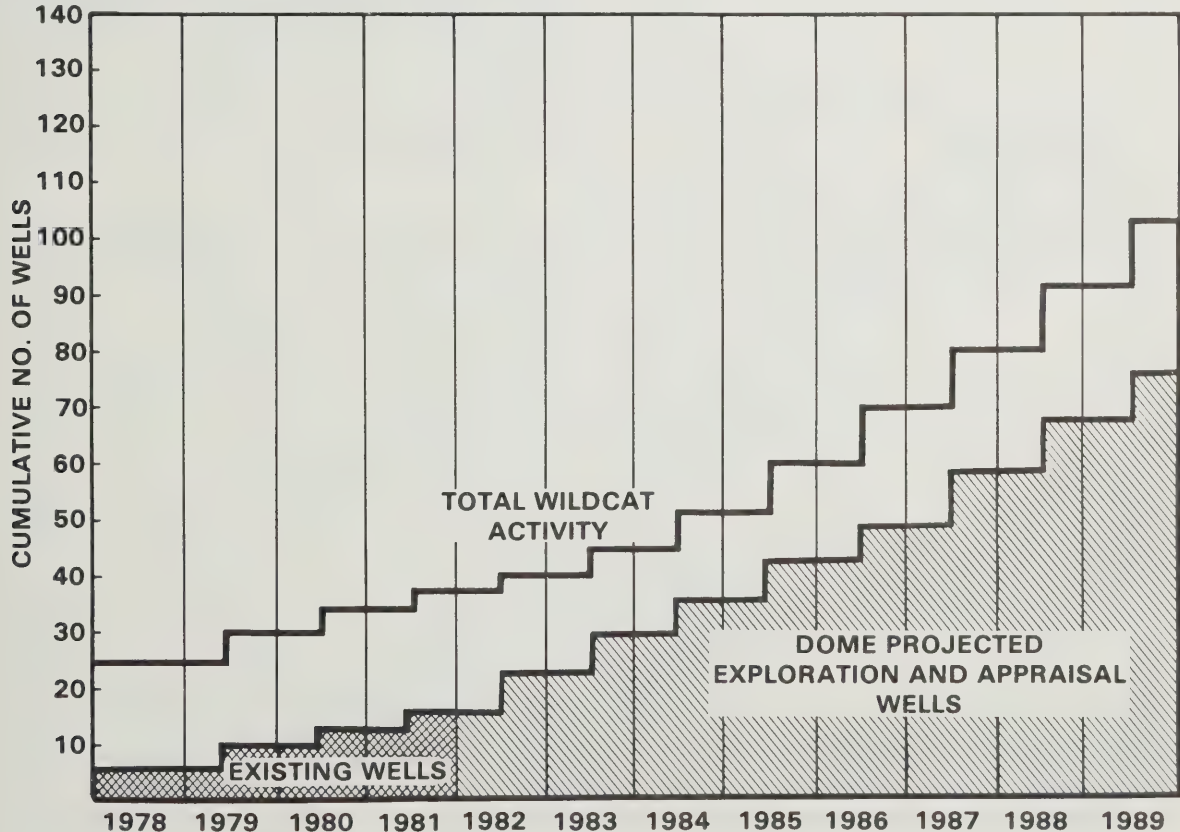
drilled in the years 1979 - 1985 and an additional 51 wildcat wells will be drilled in 1985 - 1990. The Beaufort Sea discovery rate, based on the success of the 33 exploratory wells drilled in the offshore over the past decade, provides substantial evidence that giant oil and gas fields exist, and that the rate of reserves discovery will be at least as good as that experienced in the U.K. North Sea. If we apply the Dome forecasts of 36 wildcat wells by 1985 (from discoveries in 1979) and 87 by 1990, we can predict a Beaufort Sea reserves discovery rate of 4.5 billion barrels of oil by 1985, and 7.5 billion barrels by 1990.

The shape of the curve described in Figure 3.4.1 is typical of the discovery curve for any exploration basin. Once the first major discoveries are made, and the 'key' to the basin is revealed, the largest reserves in the basin are discovered early in its exploration history. The North Sea curve represents the 10 year period from 1970 to 1979. The projection of the Beaufort Sea exploratory drilling rate over the next 10 years, is less than one quarter of that experienced in the North Sea in a similar time period. However, because of the high initial discovery rate, the reserves discovered during this period will be half of the reserves discovered in the first decade of active exploration in the U.K. North Sea.

The North Sea exploration rate increased from 11 wells per year in 1970 to a peak rate of almost 80 wells per year in



**FIGURE 3.4.1** This graph depicts the cumulative reserves discovered in the North Sea as a function of number of wildcat wells drilled, and relates it to the Beaufort picture.



**FIGURE 3.4.2** Projection of exploratory drilling activity by Dome and other operators in the Beaufort Sea to 1989.

1975; an increase of approximately 700 percent. The projection of Beaufort Sea exploration rate from the current rate of 4 wells per year to a rate of 12 wells per year is an increase of only 300%; well within the range that can be expected with continued exploration success and the advent of first commercial production.

At the time of the first major oil discovery in the North Sea the technology to produce oil in this harsh marine environment did not exist. While many companies had conducted research programs to provide a basis for subsequent design work, no company had actually built and operated a production facility capable of withstanding the severe wave forces presented by the North Sea environment. Yet, first production was achieved only five years after discovery of the first major oilfield.

Industry's position in the Beaufort Sea today is much like its position in the North Sea ten years ago. Several companies, notably Esso and Dome have conducted research programs to develop design criteria for future Beaufort Sea structures. It is worth noting that while Dome has not made the capital investments required to accelerate exploration during the past year of uncertainty, it has continued to conduct research in order to develop sound engineering and design criteria for future construction equipment, production structures and a transportation system. Based on its research and operating experience, the industry is convinced that production can be obtained from the offshore Beaufort Sea in the time frame indicated. All that is required to move the program forward is favourable results from one of the three current delineation drilling programs.

### 3.5 EARLY DEVELOPMENT SYSTEMS

The development schedules outlined in Section 3.3 describe permanent production facilities. However, it is possible to accelerate the date of first production utilizing systems known in the industry as 'early production systems.'

Early production systems were first used in the North Sea where there was a long construction time for permanent production platforms. Wells drilled from semi-submersible rigs (frequently delineation wells) were completed with subsea wellheads and connected to a semi-submersible floating rig with flexible riser pipes. A storage tanker equipped with a production process system was moved to a single point mooring system and wells were placed on production. Tankers loaded directly at the storage tanker.

Early production systems have now become common in the industry. Plates 3.5.1 to 3.5.3 illustrate a recently completed system in the Philippines.

Early production systems could have an application in the Beaufort particularly at locations where islands are used for delineation drilling.



**PLATE 3.4.1** Production from offshore fields in most areas of the world is carried out from stationary platforms (anchored to the sea floor with pilings) such as this one in the North Sea. This type of structure is unsuitable in the Beaufort Sea because it will not resist the forces caused by the moving ice.

At Tarsiut for example, by the end of 1982 there could conceivably be four or five wells capable of production and more wells could easily be drilled from the existing island. Thus, if a floating production and storage system was available along with suitable transportation, this island could theoretically be capable of producing in the summer of 1984. Recognizing this possibility, conceptual plans have been developed for an early production system for Tarsiut. This system would be portable so after permanent systems had taken over at Tarsiut, it could be moved to another site such as Koakoak. It also provides a technique for bringing the Beaufort on production slowly.

Phased development at Tarsiut using an early production system is summarized in Table 3.5.1 and shown in Figures 3.5.1, 2 and 3. Figure 3.5.1 shows how Tarsiut would be produced during open water and moderate ice conditions. The island would be connected to a single point mooring system a few kilometres away. The processing and storage tanker would be similar to that used in the Philippines except the vessel would be ice-strengthened and all of the facilities will be enclosed. By phase II (Figure 3.5.2) the permanent island has enveloped the exploration island,

# ISLAND CONSTRUCTION

## THREE PHASES

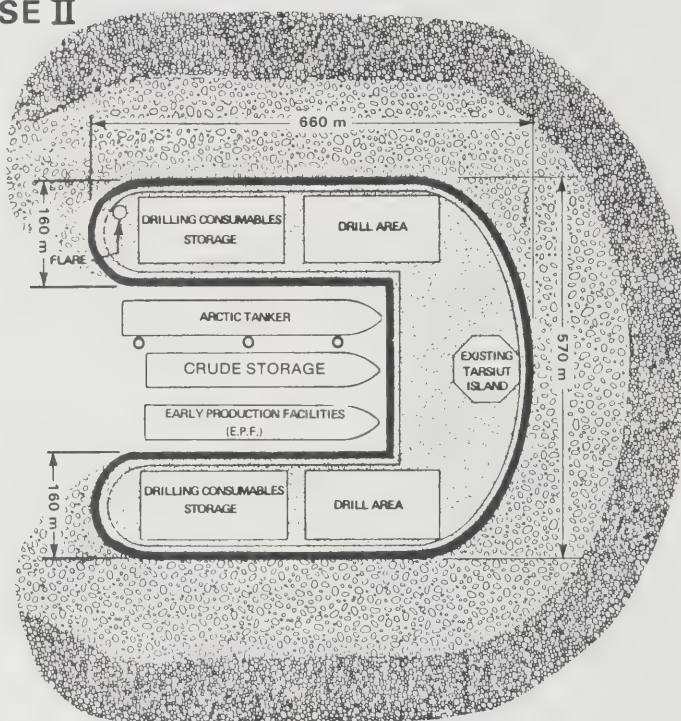
1. Expand from an exploration island to a production island open water season only using the EPF
2. Expand to a configuration that will provide protection for the EPF during the winter months.
3. Expand to a configuration that will provide protection for the permanent production facilities and complete the berm.

**TABLE 3.5.1** *Sequence of phased development at Tarsiut using an Early Production Facility (EPF).*



**FIGURE 3.5.1** *Earliest production from the Beaufort could be carried out as illustrated in this artist's rendering. Oil from a drilling island (e.g. Tarsiut) would be pipelined into deeper water where a marine riser would bring it into an EPS, much as the Philippines example, for processing, prior to loading it into a tanker.*

## EARLY PRODUCTION FACILITY LAYOUT PHASE II



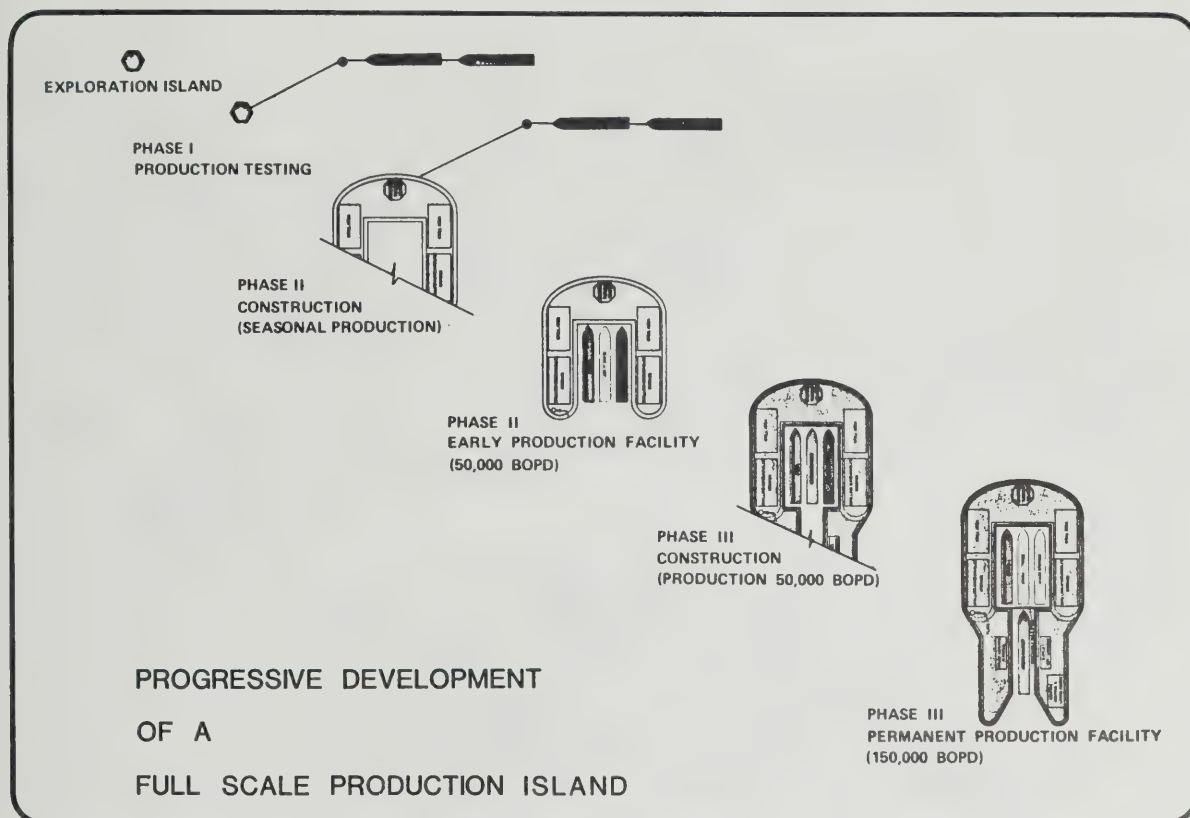
**FIGURE 3.5.2** By Phase II the permanent island has enveloped the exploration island, providing a berth for the floating processing and storage facility.



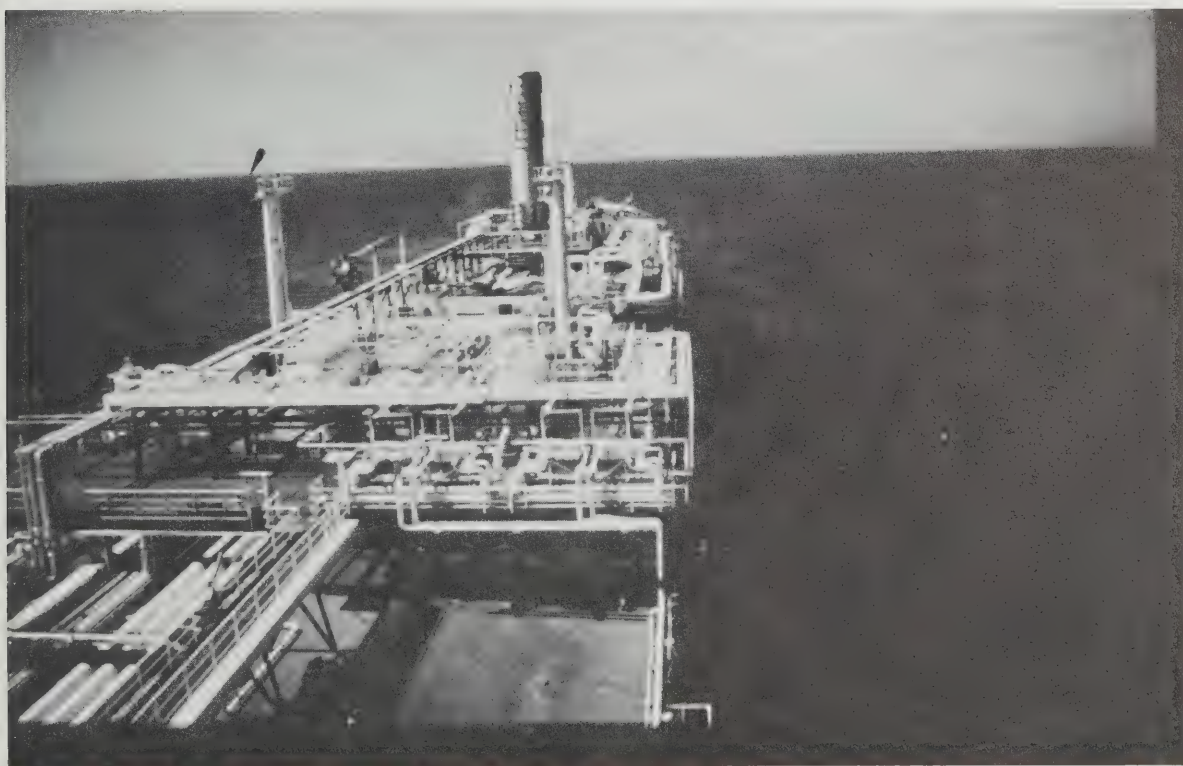
**PLATE 3.5.1** This photo shows one of the newest early production systems (EPS) presently in use in the Phillipines. An EPS is a crude oil processing and handling system which allows the earliest possible delivery of oil, before the permanent production system comes on line. Subject to approval, a similar system using an ice-reinforced tanker, could be used in the Beaufort as early as 1985.

providing a berth for the floating processing and storage facility. Seasonal production is maintained from the island while construction proceeds. Finally, in Figure 3.5.3 the permanent facilities are completed and the island can go on year-round production. Figure 3.5.4 illustrates the progressive development of the entire system.

In summary, it can be seen that using the early production system described, limited production from the Beaufort Sea can be achieved by 1985. This in itself would be a considerable accomplishment, and would go far in promoting the controlled, incremental development of the Beaufort's hydrocarbon resources.



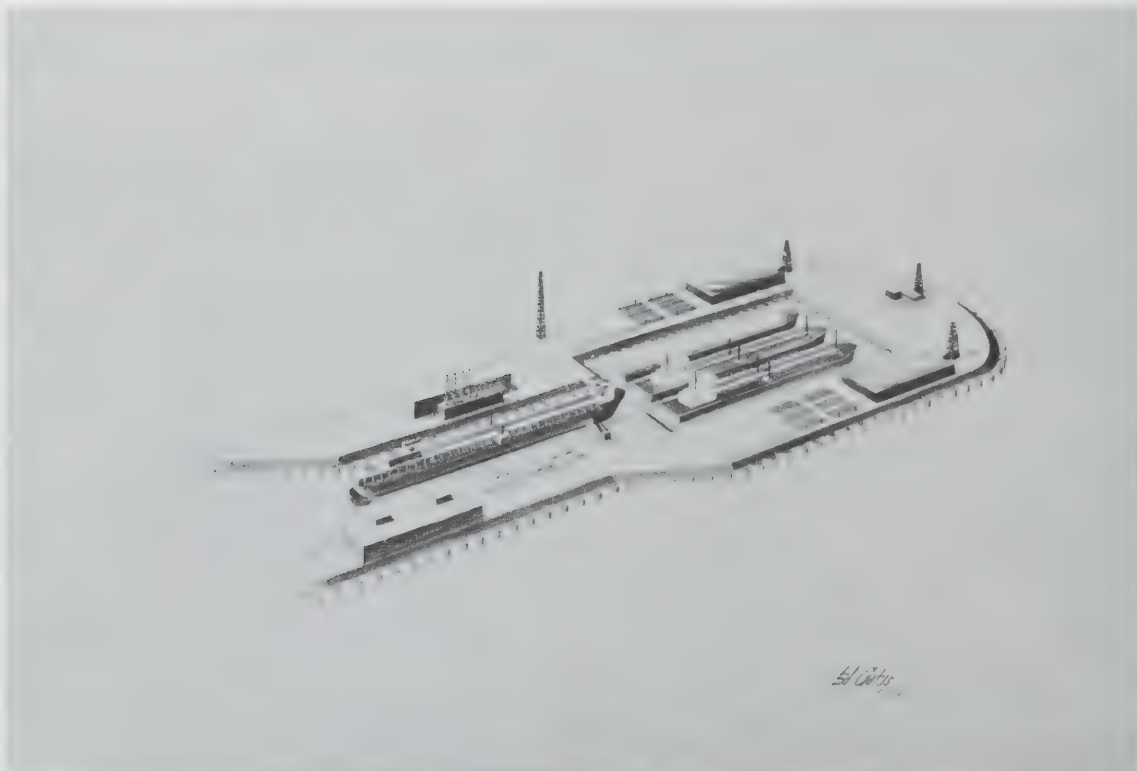
**FIGURE 3.5.4** The illustration summarizes the progressive development of the entire system.



**PLATE 3.5.2** The oil processing plant of the EPS is shown in the foreground on the deck of a modified tanker with a large enclosed gas flare projecting skyward in the background (at the bow of the ship).



**PLATE 3.5.3** *The connector between the ship and the wellhead is large, as evidenced by the men standing on it. Arctic versions would have to be ice-reinforced and protected, particularly during ice-covered months.*



**PLATE 3.5.4** *The most recent artist's rendering of the Arctic Production and Loading Atoll (APLA) being designed for the Tarsiut field is illustrated here. It will contain permanent production, crude oil storage and processing, and loading facilities to transfer oil to Arctic tankers.*

### PERMANENT PRODUCTION FACILITY LAYOUT PHASE III

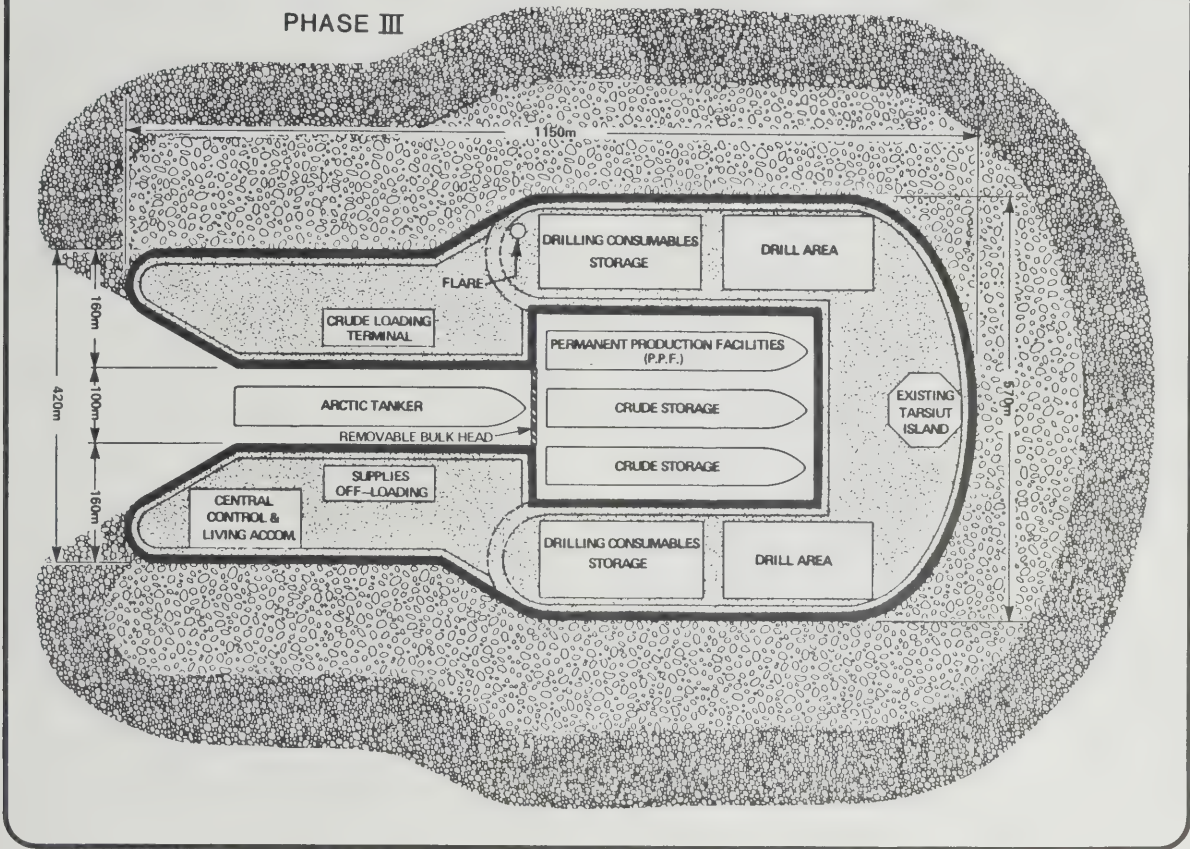


FIGURE 3.5.3 Phase III illustrates the completed layout for the Tarsiut APLA.

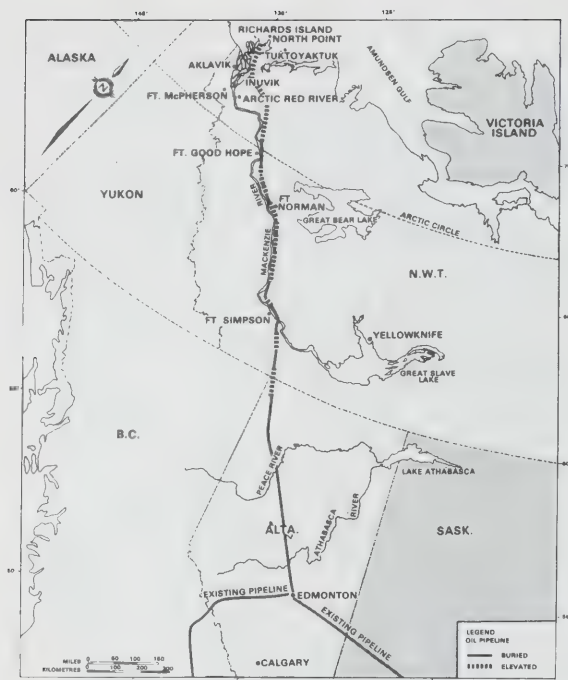
## 3.6 ALTERNATIVE TRANSPORTATION MODES

Leaseholders in the Beaufort Sea-Mackenzie Delta region are currently preparing an Environmental Impact Assessment (EIS) of hydrocarbon production in the area. This impact assessment encompasses a large part of the Northwest Territories as well as the offshore waters and covers the period 1982 to 2000.

In the course of this assessment, alternative transportation modes for hydrocarbons from the region have been extensively examined. It is considered that for either oil or gas, both pipelines and tankers or combinations of the two are feasible, and the environmental and socio-economic impacts of either system can be maintained within acceptable limits.

Pipeline systems consist of the application of developed and proven technology on land, although offshore connecting lines under Arctic conditions would be new technology. Offshore fields in the Beaufort Sea would be connected to a northern terminal of the overland line by subsea pipelines buried below the seafloor at a sufficient

depth to protect them from ice scour. The route from the Beaufort area would likely be down the Mackenzie River Valley to Fort Simpson and then on to Edmonton, a distance of approximately 1,400 miles (2,200 km), (Figure 3.6.1). From Edmonton, oil can be transported eastward or westward through existing pipelines. In all of Dome's economic analyses, the main market area has been considered to be Montreal. Therefore oil would enter the Interprovincial system at Edmonton and be moved to Toronto and onto Montreal. The Interprovincial system consists of a number of lines serving different market areas and thus its capacity varies but it is over 1 million BOPD in some sections. The capacity for moving Beaufort-Mackenzie Delta oil is also a function of the conventional Western Canada production. The marine alternative will use ice-breaking VLCC's (Very Large Crude Carriers), sailing from an offshore terminal in the Beaufort Sea to an off-loading port on the Eastern seaboard via the Northwest Passage (Figure 3.6.2) taking 20 - 30 days for a round trip. Depending on the volumes carried, a number of alternative systems exist for delivering the crude from the East coast ports to the Montreal market. These include the utilization of shuttle tankers to Portland where the oil would be pumped through an existing pipeline to Mont-



**FIGURE 3.6.1** The proposed pipeline would extend from Richards Island to Edmonton. Assuming a 36" pipeline, one can see where the pipeline would probably have to be raised above the ground, due to permafrost considerations.

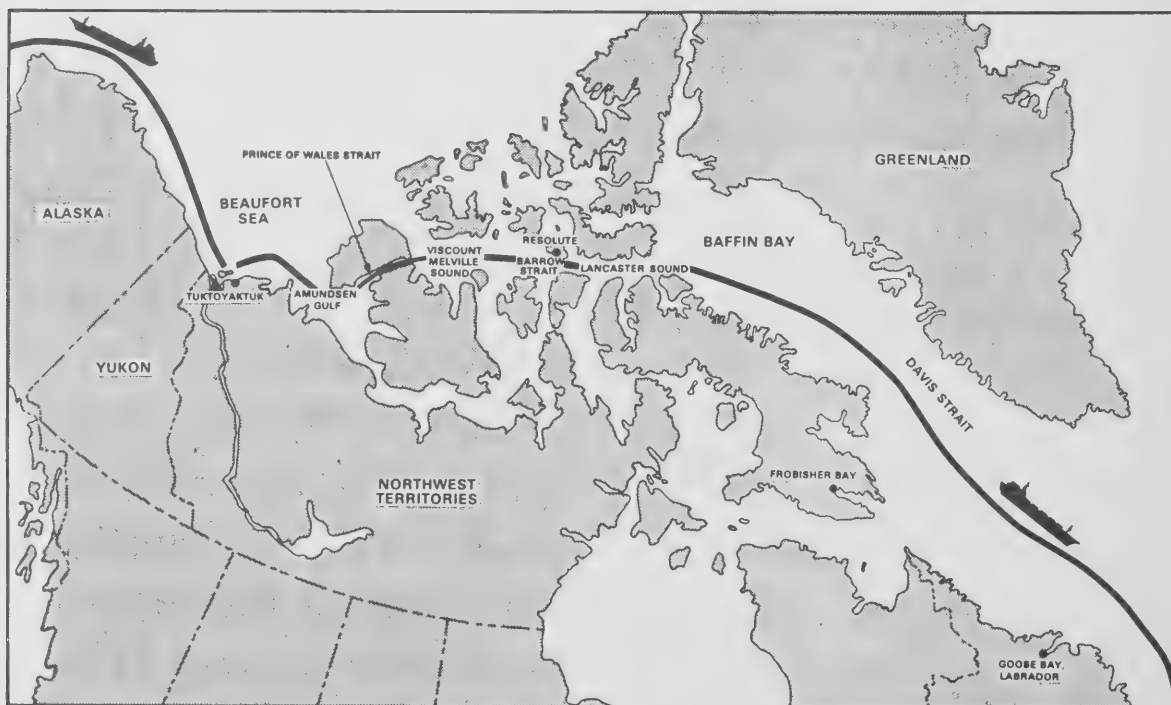
real, or the construction of a new pipeline from the Strait of Canso to Montreal.

Although there is general industry agreement on what the transportation system alternatives are, there are wide differences in the estimates for costs, economics and applications. These differences arise from individual company's experiences with the alternative systems, their interpretation of the potential of the Beaufort Sea-Mackenzie Delta Region (eg. number of discoveries, size and location of discovered fields and state of delineation) to produce hydrocarbons, the time needed to develop this potential, and their judgement on government reaction to the alternative proposals.

The following is a brief discussion of some of the primary advantages and disadvantages of the alternative transportation systems. Table 3.6.1 summarizes the relative merits of pipelines and tankers.

#### (a) Pipelines

Pipelines are a well-established mode of transport for oil throughout the North American continent and have been operating for several decades without any serious impacts. With the exception of the offshore lines, a pipeline system for the movement of Beaufort Sea oil will be little different in its design and operation than Northern pipelines (eg. Alyeska) already in existence.



**FIGURE 3.6.2** The marine route for carrying oil by tankers would proceed through the Northwest Passage to the Eastern Seaboard. An alternate, but less likely route, would head west through the Bering Strait.

**TABLE 3.6.1**  
**RELATIVE MERITS OF ALTERNATIVES**  
**FOR THE TRANSPORTATION OF BEAUFORT SEA HYDROCARBONS**

**ADVANTAGES**

**TANKERS**

- SYSTEM CAN BE JUSTIFIED AT THE EARLIEST POSSIBLE DATE
- LOWER COSTS AND GRADUAL COST BUILD-UP ALLOWS FINANCING TO BE ASSISTED BY CASH FLOW
- COST AND ECONOMIC ADVANTAGES AT LOW-MEDIUM THROUGHPUT LEVELS
- FLEXIBLE SYSTEM, CAN REACT QUICKLY TO MARKET CHANGES
- LONG TERM BENEFITS OF SHIP CONSTRUCTION, MAINTENANCE AND REPAIR
- BOOSTS ARCTIC EXPLORATION
- NEW CANADIAN TECHNOLOGY
- CANADIAN PRESENCE IN THE ARCTIC
- OFFERS EXPORT OPPORTUNITIES
- RESUPPLY OPPORTUNITIES

**PIPELINES**

- DEVELOPED TECHNOLOGY
- PROVEN SAFETY RECORD
- ECONOMIC ADVANTAGES AT HIGH THROUGHPUT LEVELS
- SHORT-TERM BENEFITS DURING PIPELINE CONSTRUCTION
- BOOSTS N.W.T. EXPLORATION
- PROVIDES NORTHERN REVENUE
- LOWER OPERATING COSTS

**DISADVANTAGES**

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>- MARINE ENVIRONMENTAL CONSIDERATIONS</li> <li>- SYSTEM IS LESS ENERGY EFFICIENT</li> <li>- NOT COMPLETELY PROVEN</li> </ul> | <ul style="list-style-type: none"> <li>- HIGH CAPITAL COST, DIFFICULT TO FINANCE</li> <li>- PRONE TO COST OVERRUNS</li> <li>- ECONOMICALLY SIZED LINES CANNOT BE QUICKLY JUSTIFIED (SUBSTANTIAL RESERVES REQUIRED)</li> <li>- REDUCED GOVERNMENT ROYALTIES</li> <li>- NO SHIPBUILDING INCENTIVES</li> <li>- ONSHORE ENVIRONMENTAL CONSIDERATIONS</li> </ul> |
|---|---|

**TABLE 3.6.1** *Relative merits of alternatives for the transportation of Beafort Sea hydrocarbons.*



**PLATE 3.6.1** *The Alyeska pipeline, 48" in size, transports oil from Prudhoe Bay, Alaska south to the open water port at Valdez. In permafrost areas the line is raised above the ground to minimized damage to the terrain.*

- (i) Advantage - Efficient and Economically Attractive at High Throughputs

The size of the pipeline to be selected is a key question. Economic evaluations indicate that an overland pipeline system has an advantage compared to a marine system at high production and throughput levels. However, this advantage only occurs when throughput levels exceed 700,000 BOPD (see Figure 3.6.3), which is higher than the probable Canadian demand for Beaufort Sea oil.

- (ii) Advantage - Benefits to the Northwest Territories

The construction of an overland pipeline will provide substantial but generally short-term benefits to the Northwest Territories in terms of employment and business opportunities. It would provide regular revenue to the North in the form of land rental and other revenues.

- (iii) Advantage - Boost to Exploration in the Pipeline Vicinity

Considerable impetus would be given to hydrocarbon

exploration along the pipeline corridor. The economics of existing and new discoveries will be enhanced by the existence of an overland transportation system.

- (iv) Advantage — More Efficient in Terms of Energy Consumed

A pipeline system requires less power and is more energy efficient per barrel of throughput. This is illustrated by Figure 3.6.4 which compares the Operational Horsepower requirements for the Tanker and Pipeline Systems.

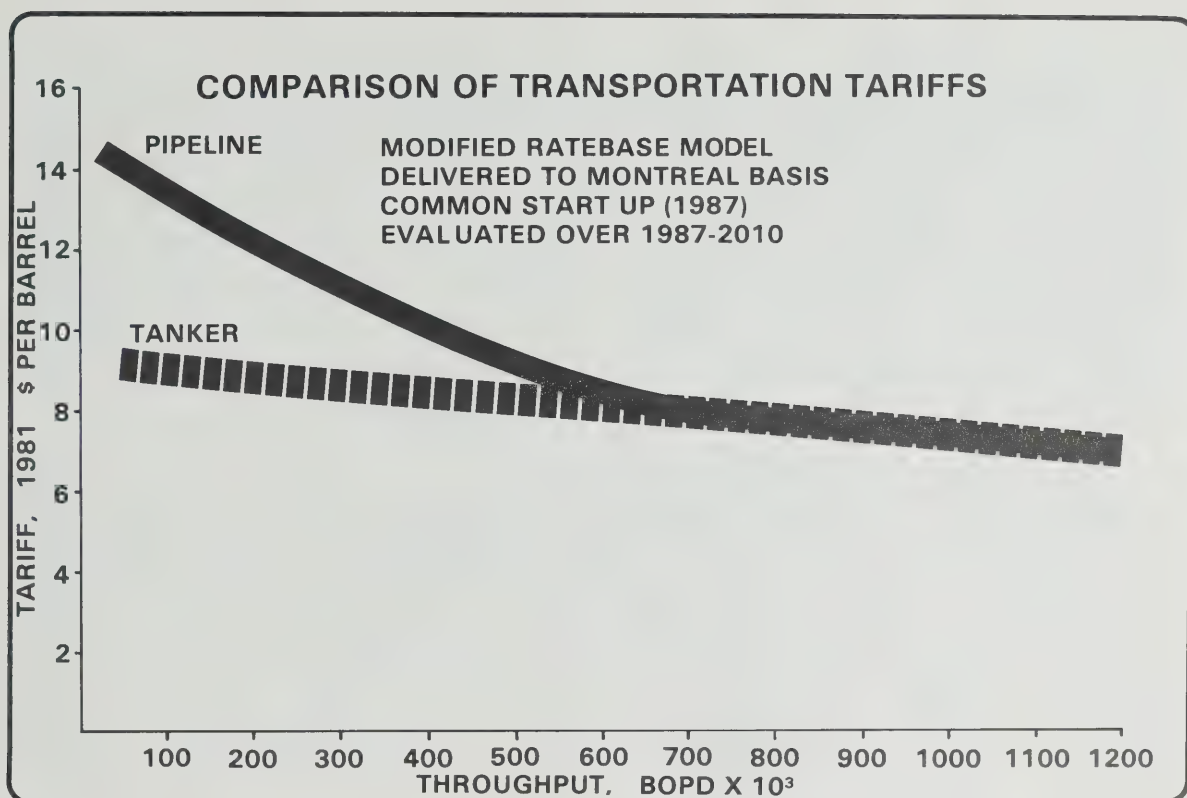
- (v) Disadvantage — Incremental Development of Offshore Beaufort not Compatible with Small Pipelines

Smaller diameter pipelines as low as 12" could technically be used to develop Beaufort Sea potential, as is proposed for the Norman Wells development. The line running from Norman Wells to Zama, Alberta, a distance of approximately 500 miles, will be operated in a "chilled" state. That is, the oil will be refrigerated so the entire line can be buried and the permafrost will not be melted. The line has only a nominal capacity of 32,000 BOPD but could possibly be increased by 10 to 15,000 BOPD. Extending this chilled line to the Beaufort Sea, although probably practical, could hardly be justified for the incremental 10 to 15,000 BOPD space available. Building a new chilled 12" line from the Beaufort Sea to Zama with 30,000 to 50,000 BOPD capacity is not economic based on current depressed price projections. Dome's analyses indicate that a tariff between \$13 to 15/bbl would be required to justify such a line. This translates into a throughput of 80 to 120,000 BOPD, well above the 12" line capacity. The practicality of building larger diameter chilled lines decreases rapidly as the line size increases. Therefore it is our belief that chilled small diameter pipelines from the Beaufort Sea-Mackenzie Delta cannot be economically justified.

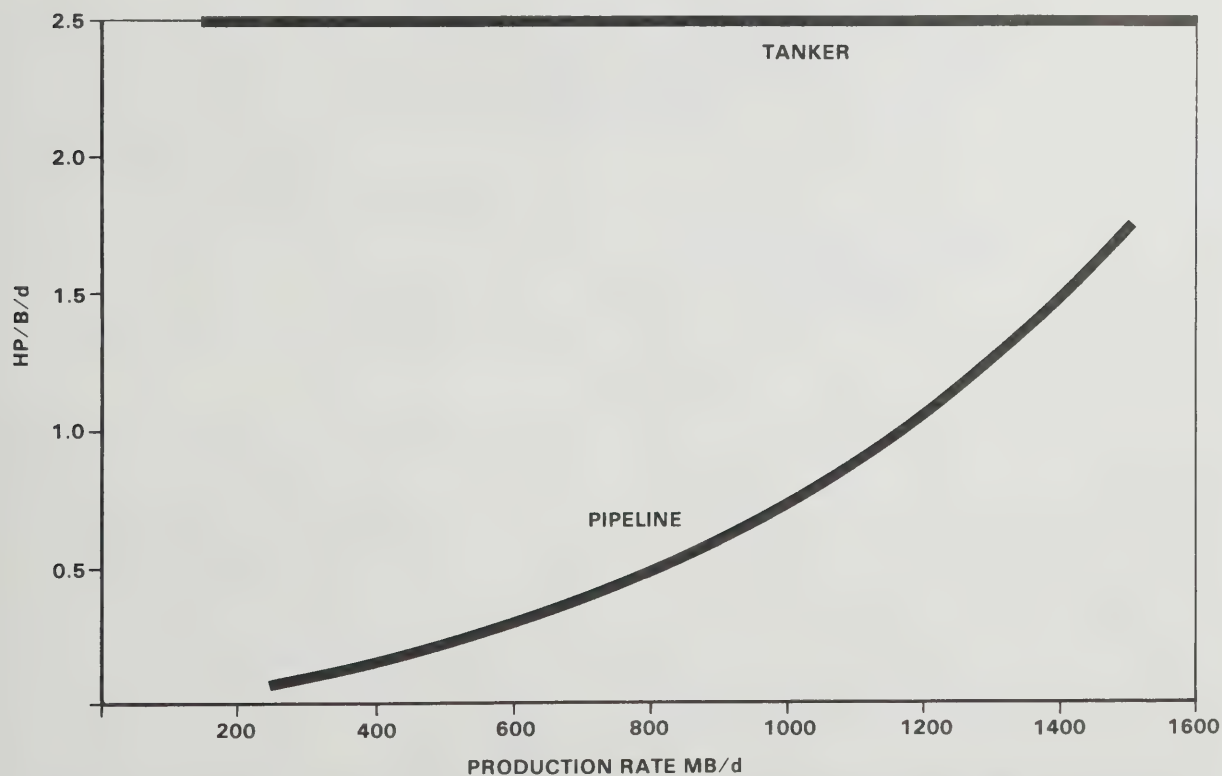
- (vi) Disadvantage - Higher Cost of Pipeline System and Financibility

Aside from chilled oil lines, the only other practicable means of pipelining through permafrost regions is to build the pipeline above ground as was done in Alaska. The cost of above ground pipelining is four times that of buried pipelines and therefore the only realistic investment would be in a large diameter pipeline (36 inch or more). To justify such an investment, substantial recoverable reserves would have to be established (in excess of two billion barrels) which would considerably lengthen the time to first oil production.

Although the details of the economics could be challenged, the general conclusion must be that the only practical and economic pipeline option is a large diameter pipeline sized to carry substantial volumes of production from the



**FIGURE 3.6.3** Comparison of transportation tariffs. Tankers are the most economically attractive mode for transporting oil until throughput levels reach approximately 700,000 BOPD, when a large diameter pipeline becomes more desirable.



**FIGURE 3.6.4** Comparison of Horsepower required to deliver one barrel of oil per day to Montreal, by pipeline and by tanker.

region. The probable line size would be 36 inches, which could carry up to 1,000,000 BOPD. Line design would be similar to the Alyeska line in Alaska. The cost of such a line is estimated at \$10 to 15 billion to carry a medium level of Beaufort production (400,000 BOPD) - a substantial investment when one considers that a further \$5 to 6 billion would be required for field development. Figure 3.6.5 shows that approximately 90% of the capital expenditures for the pipeline system are made prior to start-up and for the marine system this figure is closer to 30%. Total capital requirements for the pipeline system are three times that of the marine system for the case considered. Hence the large pipeline system will impose much larger demands on the capital markets.

As illustrated in Figure 3.6.5, capital demands for the tanker system are considerably less, and financing of the investments will be assisted by the early and incremental cash flow of the project.

(vii) Disadvantage — More Susceptible to Cost Overruns

Besides the significant difficulties in obtaining the financing required for a major pipeline system, such a project is prone to significant capital cost overruns because of the larger capital cost component and the longer construction time (up to 5 years). Alyeska, for instance was originally estimated to cost \$800 million and finally cost \$8 billion.

Because the marine transportation system is built in

smaller separate units, it is much less susceptible to cost overruns. Shipyard contracts are very competitive and it is likely that fixed priced contracts can be obtained.

(viii) Disadvantage — Reduced Present Value of Development and Government Royalties

Due to its deferred start-up, the present value of Government Royalties and taxes is considerably less with the pipeline system compared to tankers. Based on transporting 8 billion barrels of oil over twenty years, the difference in present value of royalties and taxes is \$2 billion (discounted at 15% per annum).

(b) Tankers

Most of the world's crude oil is moved by tanker. Tankers as large as 550,000 tonnes (4 million barrels) carry oil from the Middle East, Africa and South America to markets all over the world. Tankers are a very well established mode of transportation and considerable amounts of historical data are available with regard to their operations and safety. These aspects are discussed further in Sections 4.0 and 5.0 of this submission. Dome has examined the safety record of tankers in great detail and believes that tankers can be constructed that will be able to ply the Arctic waters year-round with minimal risk or impact.

The present Dome tanker is designed to carry 200,000 tonnes or 1.5 million barrels of oil, equivalent to approxi-

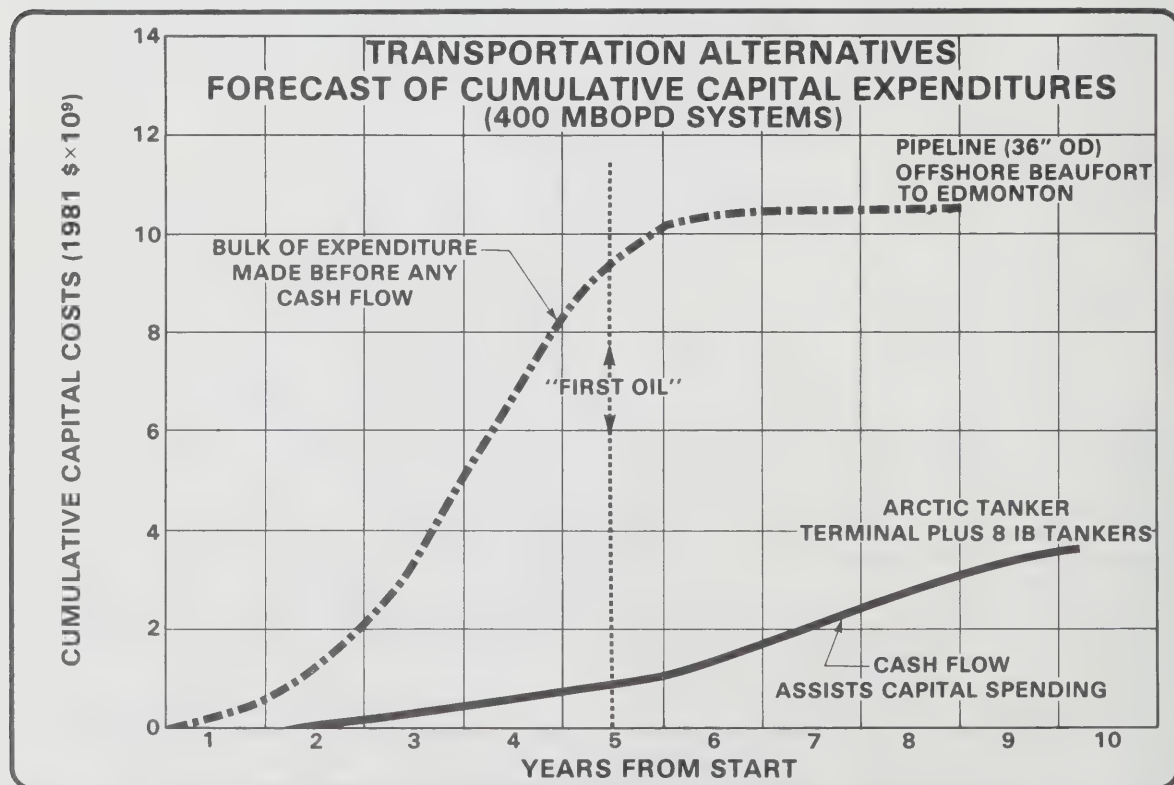
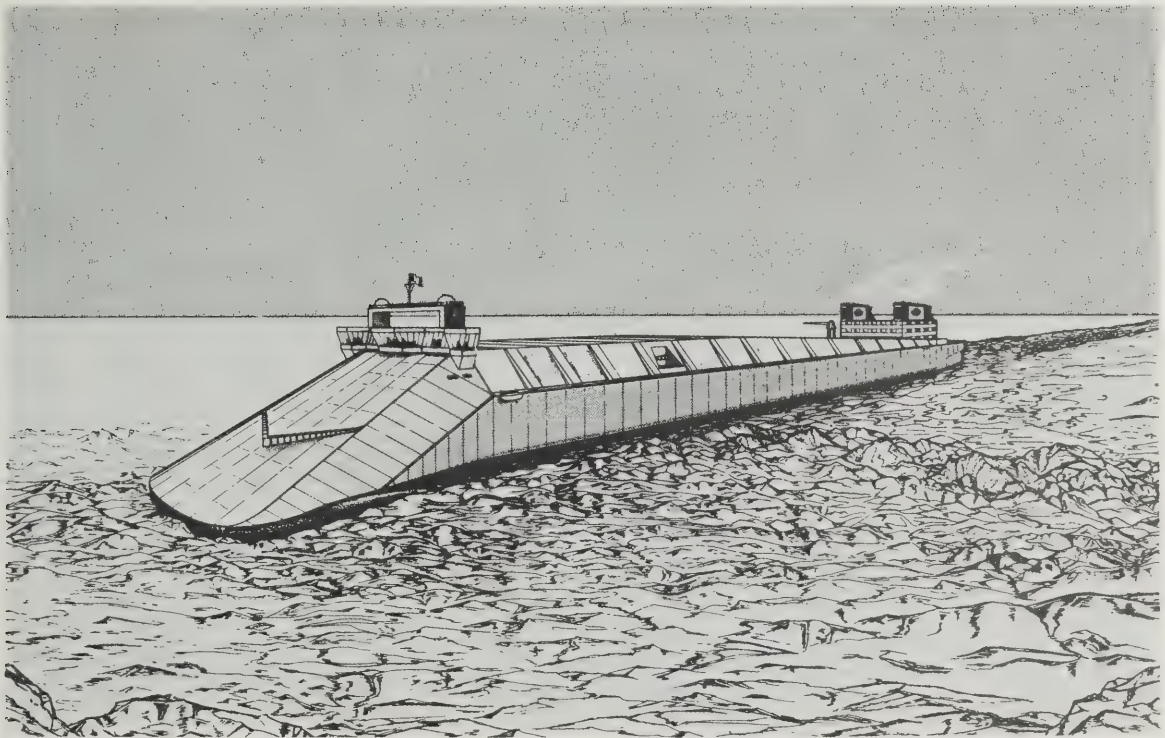


FIGURE 3.6.5 Transportation alternatives — Forecast of cumulative expenditures.



**PLATE 3.6.2** This sketch is an artist's conception of a future Arctic tanker to be used on a year-round basis through the Northwest Passage.

mately 50,000 BOPD of production (smaller capacities are feasible and practical if required for a better match with production levels). They have an icebreaking hull and will be powered by engines generating up to 150,000 shp. The ice Class 10 hull rating will meet all the Canadian Coast Guard requirements for year-round operation anywhere in the Arctic. The oil will be stored in centre tanks, isolated from the outer hull by 12-30 ft wide water ballast tanks depending on locations in the hull. The vessels will be equipped with highly advanced ice navigation equipment and Canadian personnel with special training and experience in sailing in Arctic waters. They will take about two years to build in a world scale shipyard at a cost of \$350 million (1981).

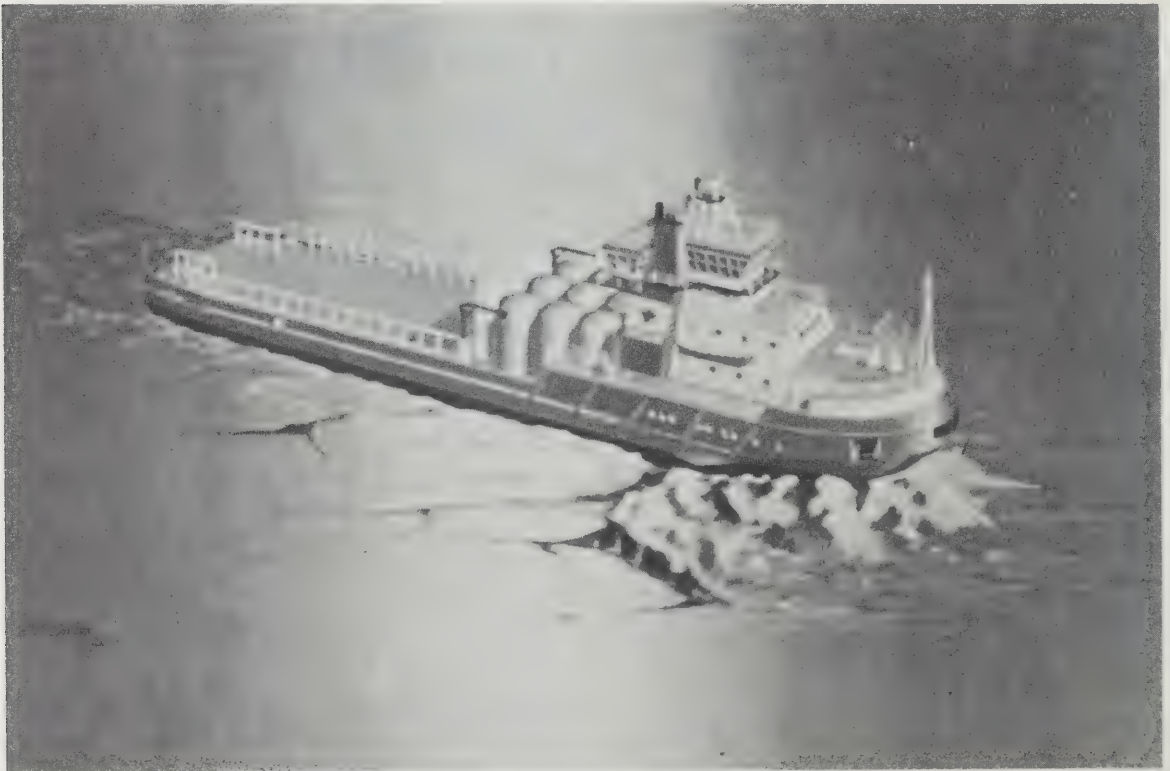
The evaluation of the tanker system is based on Dome's design and cost of the icebreaking tanker. In the Beaufort a large research and development effort has been focused by Dome on the development of year-round transportation systems. Progressive technology has combined with research and actual field operations in small increments to gradually increase our capabilities. In the case of icebreaking, the first commercial icebreakers in the Beaufort Sea were Dome's Class 2 icebreaker supply boats brought in during 1976. These vessels demonstrated a good capability of working in first year ice two to three feet thick. Considerable experimentation and research was performed with these vessels examining their interactions with ice under a variety of conditions. These are working ships engaged in supporting

and protecting the drillships while they are moored over their drilling locations in the Beaufort Sea. After two years of tests Dome chartered the John A. Macdonald for a year. She is a Class 3 icebreaker and was used to perform research during the late season drilling period when drilling operations were conducted in ice up to nearly 3 feet thick. Data from this research program was used to design the Kigoriak, a Class 4 icebreaker which sailed into the Beaufort in the fall of 1979. The Kigoriak was engaged in research throughout the winter of 1979 and 1980 making it the first North American ship to work year-round in the Arctic. The Kigoriak has demonstrated a tremendous capability to handle first year ice five to six feet thick and has demonstrated the capability of working year-round in first year ice.

Other research relative to icebreaker operations have included collecting ice data along prospective tanker routes, measuring the mechanical characteristics of ice throughout the year, and studies on ice features such as pressure ridges, rubble fields and ice islands. These data, combined with data from the Kigoriak research program, led to the design of the Robert LeMeur, a Class 4 supply vessel, currently under construction in Vancouver and scheduled to be in operation in the Beaufort in the summer of 1982. This vessel incorporates a number of improvements to the Kigoriak and has a hull form and general configuration almost identical to that of the proposed Class 10 tankers. In many ways, it is in fact a one-third scale



**PLATE 3.6.3** Research conducted in conjunction with the Canadian Coast Guard Icebreaker John A Macdonald made a significant contribution to the progressive development of icebreaker designs which is demonstrating the feasibility of year-round shipping in the Arctic.



**PLATE 3.6.4** The Robert LeMeur, Dome's newest icebreaker supply ship is presently being built in Vancouver. This vessel incorporates many new features which may be used on future Arctic Tankers.

model of the tanker. The next step in the sequence is a Class 10 icebreaker which will demonstrate the feasibility of sailing in all types of ice on a year-round basis, anywhere in the Arctic.

Similar research and development has been underway with environmental monitoring systems, ice detection systems and navigation systems. Dome's unique knowledge in the design of icebreaking vessels is the basis of the design and cost assumptions summarized in Table 3.6.1.

- (i) Advantage — Economically attractive at low to Medium throughput levels

Economic evaluations have indicated that the tanker system requires a lower tariff per barrel of throughput than the pipeline alternative, for rates up to 700,000 BOPD. This is shown in Figure 3.6.3.

- (ii) Advantage — Lower Threshold of Reserves to Justify Development

The minimum economic level of development for the Beaufort with a pipeline transportation system has been estimated at 2.5 billion barrels of proven recoverable reserves of oil and a 350,000 BOPD production rate. However for tankers, the minimum threshold level for full scale development is 700 million barrels of proven reserves and a production rate of 100,000 BOPD.

The requirement to prove 2.5 billion barrels of reserves to justify a pipeline would defer start-up of Beaufort Sea oil production until 1990 at the earliest, based on Dome's forecast of rate of confirmation of proven reserves with time (see Figure 3.6.6). However, a 2 tanker system requiring only 700 million barrels of proven reserves could be delivering oil to the Eastern seaboard by as early as 1985. It is important to remember that the late 1980's are probably the period of maximum imbalance (deficit) in the Canadian supply/demand picture. This picture is predicted to improve in the 1990's with the development of East Coast and tarsands production. Thus Dome believes that the Beaufort Sea can make an early contribution to the crude oil supply position with the use of tankers but probably cannot contribute until at least 1990 with a pipeline system.

The timing advantage of the tanker system, in both start-up and flexibility to expand upwards, is particularly important in another context. The cost of exploration in the Beaufort Sea is considerable and a substantial portion of these costs are borne by the Government of Canada on behalf of the Canadian nation. It is important that the exploration investment in the Beaufort Sea yields some positive returns at the earliest possible date. Production from the Beaufort Sea in the mid to late 1980's, using a Marine transportation system, will realize this objective and will justify current and future incentive programs for mineral exploration in these frontier regions.

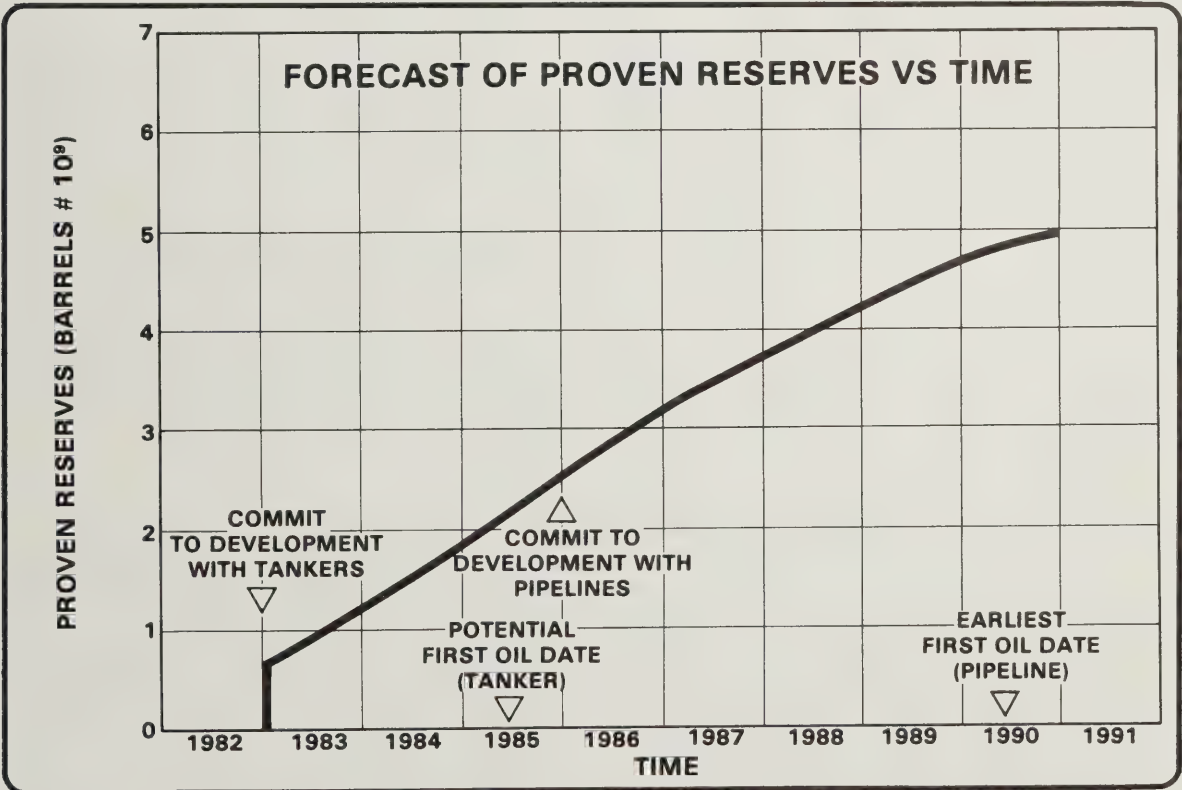
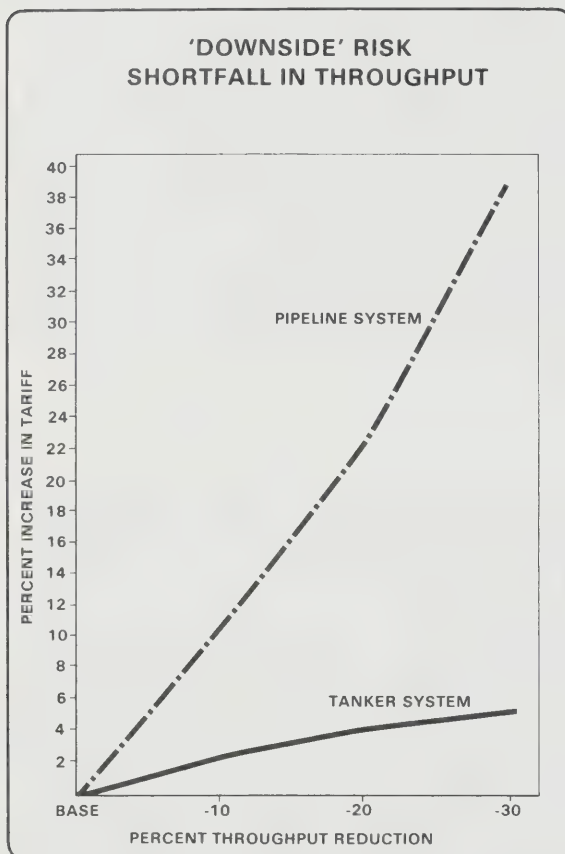


FIGURE 3.6.6 Forecast of proven reserves versus time required to justify marine and pipeline transportation systems.

(iii) Advantage — Flexibility

Flexibility in adopting to market demand or market location is another important factor in favour of using tankers. Increases in demand for Beaufort oil due to foreign supply interruption can be met swiftly by adding further tankers to the fleet with a lead time (ship construction) of 24 months. Reductions in demand can be accommodated through slow steaming and/or laying up of tankers. Since the tanker capital costs are relatively small, this is more economically attractive than is operating a pipeline below its designed level (Figure 3.6.7 illustrates the effect of a reduced throughput on Tariff).



**FIGURE 3.6.7** The effect of oil throughput reductions on the tariff for a pipeline system as compared to a tanker system.

The tanker option provides the opportunity to gradually improve the transportation and production systems. The development starts out with one production system and one or two tankers and builds up over a period of years. Experience will enable engineers to improve the designs with each system. The pipeline system on the other hand offers little opportunity or reason for improvement.

Tankers also have the advantage of delivering to different markets as the need arises, which in the case of the Beaufort Sea could include either the west or east coast of Canada and/or possibly foreign destinations. Furthermore, Arctic

Class tankers built for Beaufort oil, can be used to initiate early production from other remote Arctic areas such as the High Arctic, where the threshold reserves of oil required to justify a pipeline could be even greater.

(iv) Advantage — Development of Canadian Technology

Until a few years ago the state of the art in icebreaking technology resided in countries other than Canada and the technology for conducting offshore exploration and development of activities in the Arctic did not exist. As a result of the Beaufort operation the state of the art technology for icebreaking now resides in Canada and a substantial capability for operating offshore in the Arctic on a year-round basis is now available. This technology could be used in other countries and is therefore exportable. A combination of Arctic technology with an Arctic oriented industrial capability is an even more exciting prospect.

The spin-off technology associated with Arctic icebreaking technology could rival that of the space industry. Many high technology systems that are presently being developed and will be used will have numerous applications outside of the oil industry.

(v) Advantage — Enhancement of Arctic Islands Sovereignty

The question of Arctic Island sovereignty has always been an international issue. The ability of a nation to defend its territory is a measure of sovereignty. Clearly our sovereign claim to the Arctic Islands and the waters in between would be enhanced if the year-round marine capability to reach these islands could be achieved. National Defense ability would also be enhanced with year-round Arctic marine systems.

(vi) Advantage — Boosts Mineral Exploration and Development in the Arctic

The development of a Marine transportation system, operating through the Northwest Passage will provide a substantial boost to hydrocarbon and other mineral exploration and development programs throughout the Northern Frontier.

(c) Conclusion

The foregoing has briefly reviewed some of the advantages and disadvantages of the two major systems under consideration for moving Beaufort oil to market. There are many others but it was not the intent that all would be covered here. Some further information is provided in subsequent sections of our submission. However, based on our review, Dome believes that there are many compelling reasons for initiating Beaufort oil production at an early date, and that Arctic tankers represent the only system that can deliver this oil in the time frame demanded.

## **SUMMARY OF SECTION 4.0**

### **RESEARCH IN SUPPORT OF DEVELOPMENT**

4.0 A great deal of research has been performed in relation to all phases of existing and proposed oil industry activities in the Beaufort Sea-Mackenzie Delta region.

4.1 Extensive ice and other physical research programs over the past decade have demonstrated that offshore petroleum operations in ice infested waters are clearly feasible now and in the future.

4.2 To support the proposed tanker transportation scheme, a highly sophisticated remote sensing, communications and navigation system (REMSCAN) is being developed; it will ensure the safest and most efficient passage of icebreaking tankers through the Arctic seas.

4.3 Major strides have been made in the field of oilspill prevention, countermeasures and clean-up under Arctic conditions. The industry's increased understanding of the behavior of oil in ice, and the new techniques-technologies developed to deal with spills under these conditions, allows us to conclude that effective responses to oilspill incidents can be mounted.

4.4 Biological research programs have and are continuing to be carried out to address all important issues related to offshore activities. To date no significant biological problems have been detected, and with the application of appropriate measures combined with continued monitoring, none are expected in the future.



4.0 RESEARCH IN SUPPORT OF DEVELOPMENT

During the decade and a half that the industry has been active in the Beaufort Sea - Mackenzie Delta area, a great deal of research has been performed in relation to all phases of ongoing and proposed oil industry activities. The following section of the submission reviews some of the more pertinent work in the fields of ice and physical research, remote sensing, oilspill research, and marine biological research. Emphasis has been placed on work that is most relevant to Dome's proposal to ship oil to market by icebreaking Arctic tankers.

4.1 ICE RESEARCH

The major influence on offshore operations in the Western Arctic, and the transportation of hydrocarbons from the area, is the presence of ice for much of the year. In the southern Beaufort Sea, ice is present, on average, for eight to nine months of the year. In the more difficult sections of potential tanker routes, such as Viscount Melville Sound, the open water period is often only of a few weeks duration, and in some years, the ice may never clear. Therefore, the systems which have been developed for petroleum operations in the offshore Arctic have been shaped by the need to operate in this environment. The experience gained during the last decade, plus the extensive ice research conducted in Canada, have demonstrated that offshore petroleum operations in these waters are not only feasible, but in some respects are easier than in open water areas. For example, severe storms do not lead to the extreme sea states which can occur in such areas as the North Sea and the Canadian East Coast.

(a) Effects of Ice on Offshore Petroleum Technology

Table 4.1.1 shows in summary form, how the presence of ice influences the various facets of offshore petroleum operations. Exploratory drilling is normally conducted from floating vessels. Such an approach has been successfully used by Dome Petroleum in the Beaufort Sea during the three to four months of open water. The safety and

efficiency of these operations has been enhanced by ice strengthening, special designs to lower mooring loads, and stringent ice management programs. These techniques have enabled the drilling season to be extended into the early winter period.

The area of the Beaufort Sea which is most prospective for hydrocarbons is relatively shallow. In the nearshore areas, artificial islands can be used, from which normal land drilling operations can be conducted, and which has the advantage of providing year-round drilling. Island building technology has gradually developed to the point where islands can now be built in water depths of 75 feet in one season.

The experience gained from the nineteen islands built to date for exploration in the Beaufort Sea, plus the accompanying research programs, now provides confidence that islands can also be used for production platforms, and in even greater water depths. Research indicates that production platforms based on island technology can be designed to withstand the worst ice loads caused by the moving ice (Figure 4.1.1). A major emphasis is currently on improving construction efficiency so that maximum use can be made of the short open water period available for construction. To this end, the steeper slopes created at the Tarsiut Island and the use of caissons at the water line have greatly reduced fill requirements over that needed in construction of the more conventional artificial islands built by Esso to date.

Offshore pipelining in the Beaufort Sea could be affected in several ways by ice. The short open water season reduces the construction efficiency of conventional pipelaying equipment. On the other hand, in the landfast ice zones, the ice itself could be used as a working platform for pipeline construction. Deep ice features scour the soft sediments of the sea floor in the shallower regions of the Beaufort Sea. Pipelines placed on the sea floor will have to be protected against this ice action. The most likely solution to this problem is to place the pipeline in a trench.

TABLE 4.1.1

EFFECTS OF ICE ON OFFSHORE PETROLEUM TECHNOLOGY

EXPLORATORY DRILLING

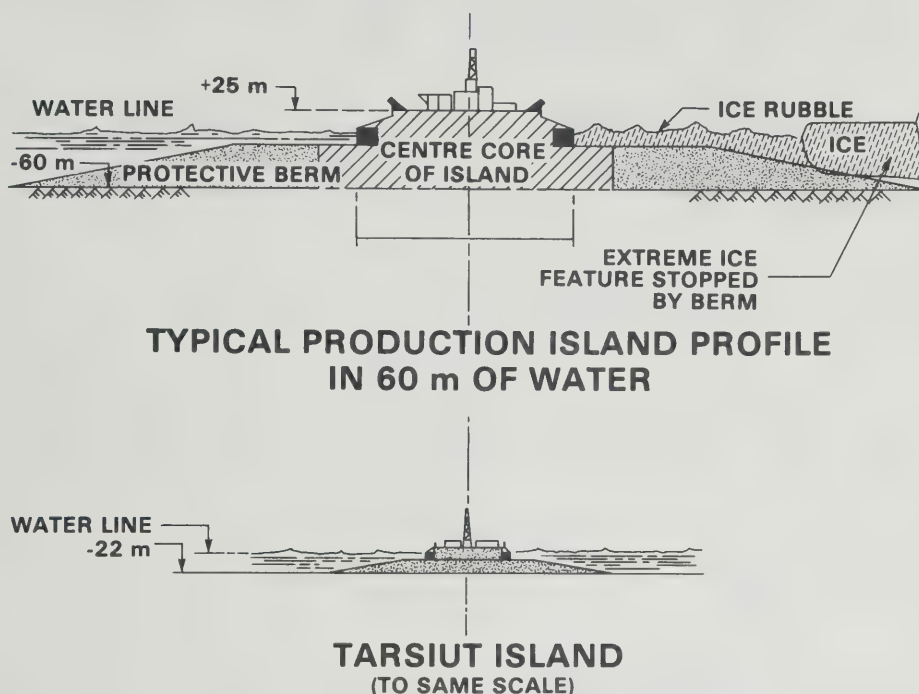
- SHORT OPEN-WATER SEASON FOR FLOATING DRILLING.
- CAN BE EXTENDED BY ICE STRENGTHENING and special designs to lower mooring loads.
- artificial island attractive for shallow water.



**PLATE 4.1.1:** *Dome's offshore drilling in the Beaufort is presently conducted mainly from conventional ice-reinforced drillships which can operate only in moderate amounts of ice. The use of icebreakers around the drillships has increased the drilling season to approximately one-third of the year.*



**PLATE 4.1.2:** *Issungnak, site of one of the more recent offshore oil and gas discoveries, was built by Esso Resources Canada Limited. It is located about 30 kilometres north of the nearest Arctic coastline in 65 feet of water. Issungnak required the dredging of five million cubic metres of sand from the sea floor.*



**FIGURE 4.1.1:** Research indicates that production platforms based on island technology can be designed to withstand the worst ice loads caused by moving ice.

## (b) Typical Ice Conditions in Areas of Interest

### (i) Beaufort Sea

Ice conditions vary from complete ice coverage in the winter to open water along a narrow coastal strip during the brief polar summer. Ice drift is dominated by the Beaufort Gyre which circulates in a clockwise direction. The open water period naturally has a considerable influence on construction and logistics. From our own experience over the last 8 years, plus government ice maps going back 20 years or more, we know that in an average year, break-up will be complete by mid-July near shore, clearing somewhat later further out; freeze-up usually commences about mid-October giving a gross average open water period of 90 days, near shore.

In bad ice years, as seems to occur every few years, break-up may be two or three weeks late, and freeze-up two or three weeks early, reducing the season by almost half.

Typical winter ice features are shown in Figure 4.1.2. Landfast ice extends out to about the twenty metre water depth, but has a smooth surface only out to about the five metre depth. Beyond that, there are usually numerous first year ridges which are formed during the early winter before the ice becomes landfast. Many of these ridges are grounded, forming anchor points for the landfast ice. The grounding action by these and the occasional multi-year ridge proba-

bly causes the seabed scours which are numerous in the area.

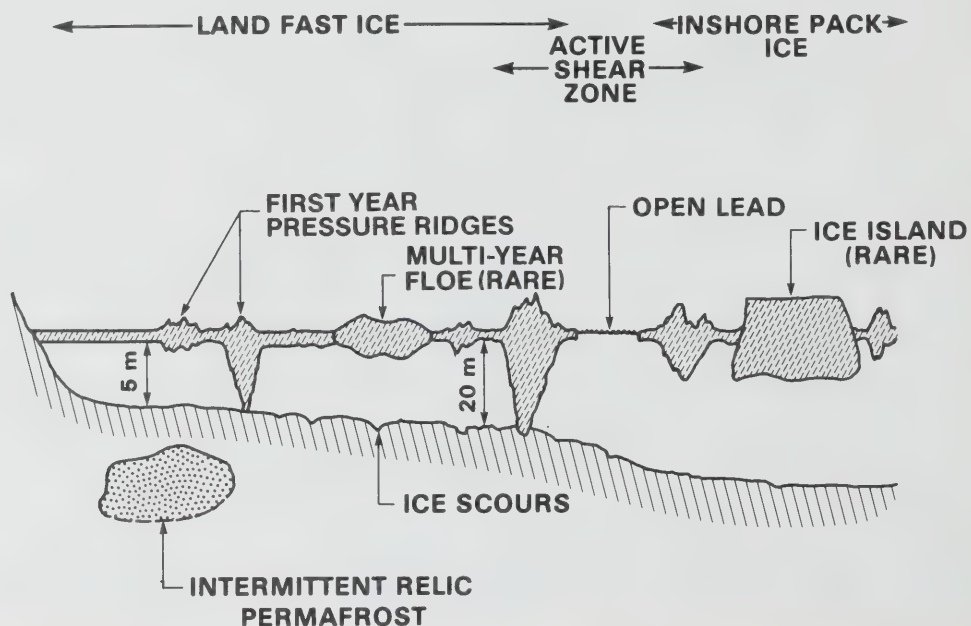
Freeze-up usually commences during October and by the end of October, new ice has generally formed in the sheltered shallow bays, and at the edge of the polar pack. By early November, a thin ice cover usually extends over the whole area, although it is easily moved and broken by autumn storms. Gradually, however, a stable sheet of fast ice extends out from shore. By mid-November, fast ice extends out to about the 6 m water depth, and is 30 to 60 cm thick.

During the dark months of November and December the relatively thin ice which is not yet landfast, is continually broken and ridged by wind action. It is during this period that most of the first year ridges in our area of interest are formed. Many of these ridges ground on the sea bed and help stabilize the ice so that by January a sheet of fast ice extends out to about the 20 m water depth. It generally remains established at this position for the rest of the winter.

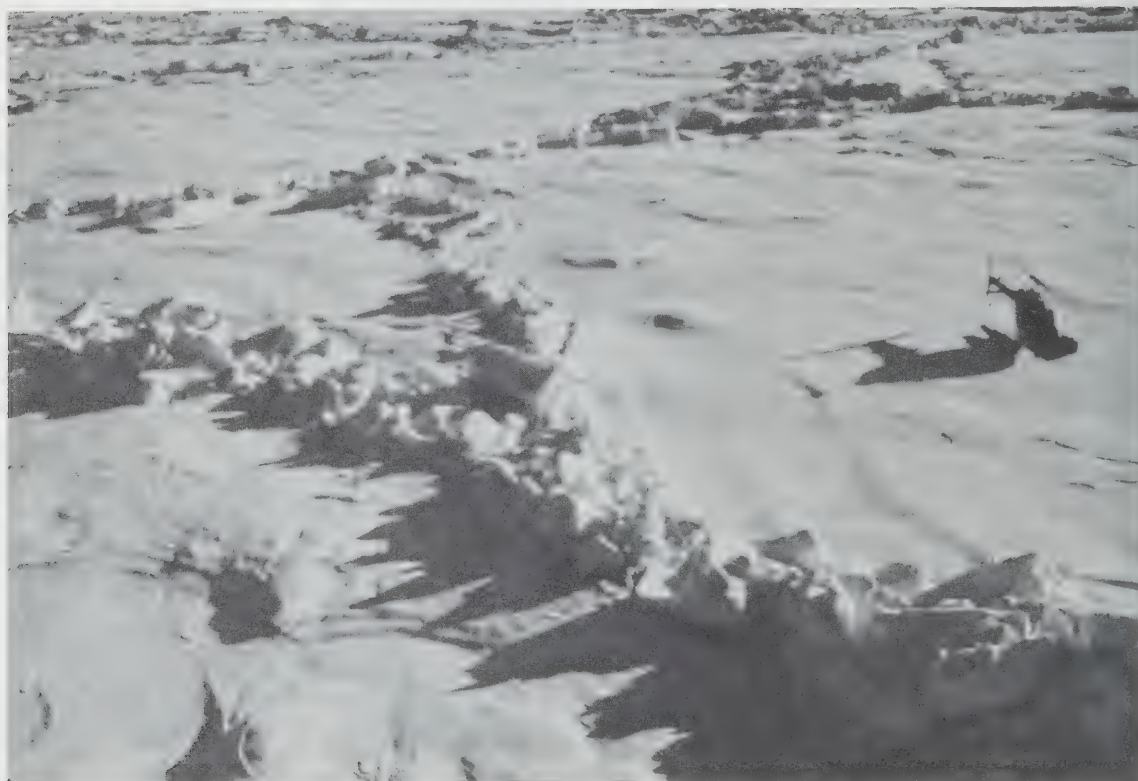
The annual ice reaches a maximum thickness of 2 m by late April, but in many areas it is ridged.

The ridges generally have sail heights below ten feet (3 m) and measurements of selected first year ridges show that ridge keels are about four times the sail heights. However,

## TYPICAL WINTER ICE FEATURES, BEAUFORT SEA JANUARY - MAY



**FIGURE 4.1.2:** *Typical winter ice features in the Beaufort Sea.*



**PLATE 4.1.3:** *The Beaufort Sea is generally covered by ice for 8-9 months of the year. Pressure ridges such as those illustrated here form when ice floes collide and they are particularly common in the transition ice zone.*

first year ridges are largely an accumulation of unconsolidated ice blocks and do not present as severe a loading condition for marine structures as do multi-year ridges.

Multi-year ridges are fully consolidated and although rarer in the coastal zone, they do appear to govern the ice loads on marine structures in this area. Multi-year ridges with thicknesses of up to fifty feet are relatively common in the Beaufort Sea. Statistical techniques can be used to define the extreme ridge at a particular location. However, in the shallow areas the water depth will probably determine the design ridge thickness.

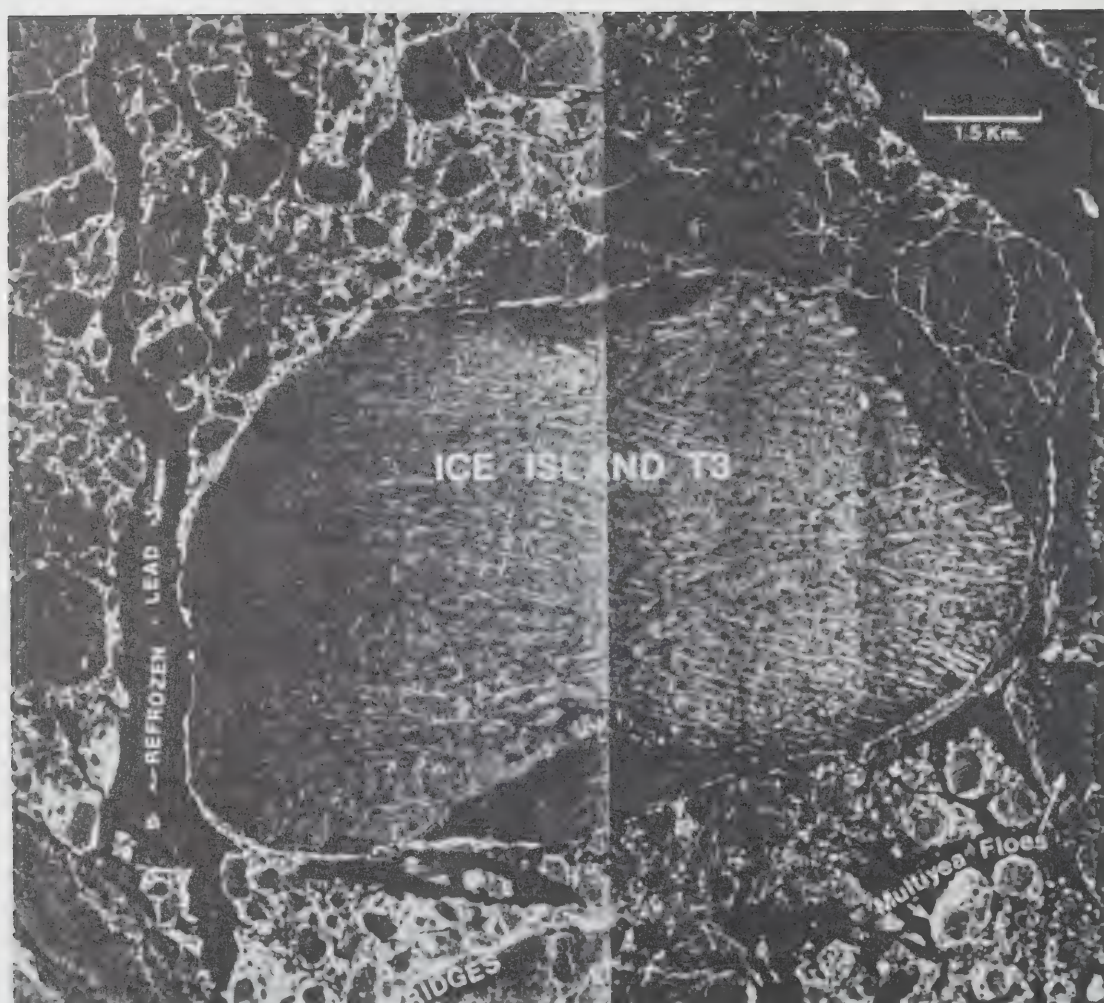
For structures in water deeper than about 25 m, the risk of collision by massive ice islands has to be considered, but the return period of such collisions is estimated to be greater than a hundred years.

#### (ii) The Eastern Tanker Route

The preferred easterly route heads through Amundsen Gulf, Prince of Wales Strait, Viscount Melville Sound, Lancaster Sound, Baffin Bay, Davis Strait and the Labrador Sea; a distance of about 4,400 km. All kinds of ice conditions can be found along the route including first year ice, multi-year ice, pressure ridges and icebergs. A general summary of ice conditions along the route is provided in Figure 4.1.3; it covers multi-year ice concentrations, maximum first year ice thickness, ridge frequencies, open water periods and iceberg densities. Work continues to refine our understanding of multi-year thicknesses and floe sizes, in order to optimize tanker designs and improve transit times.

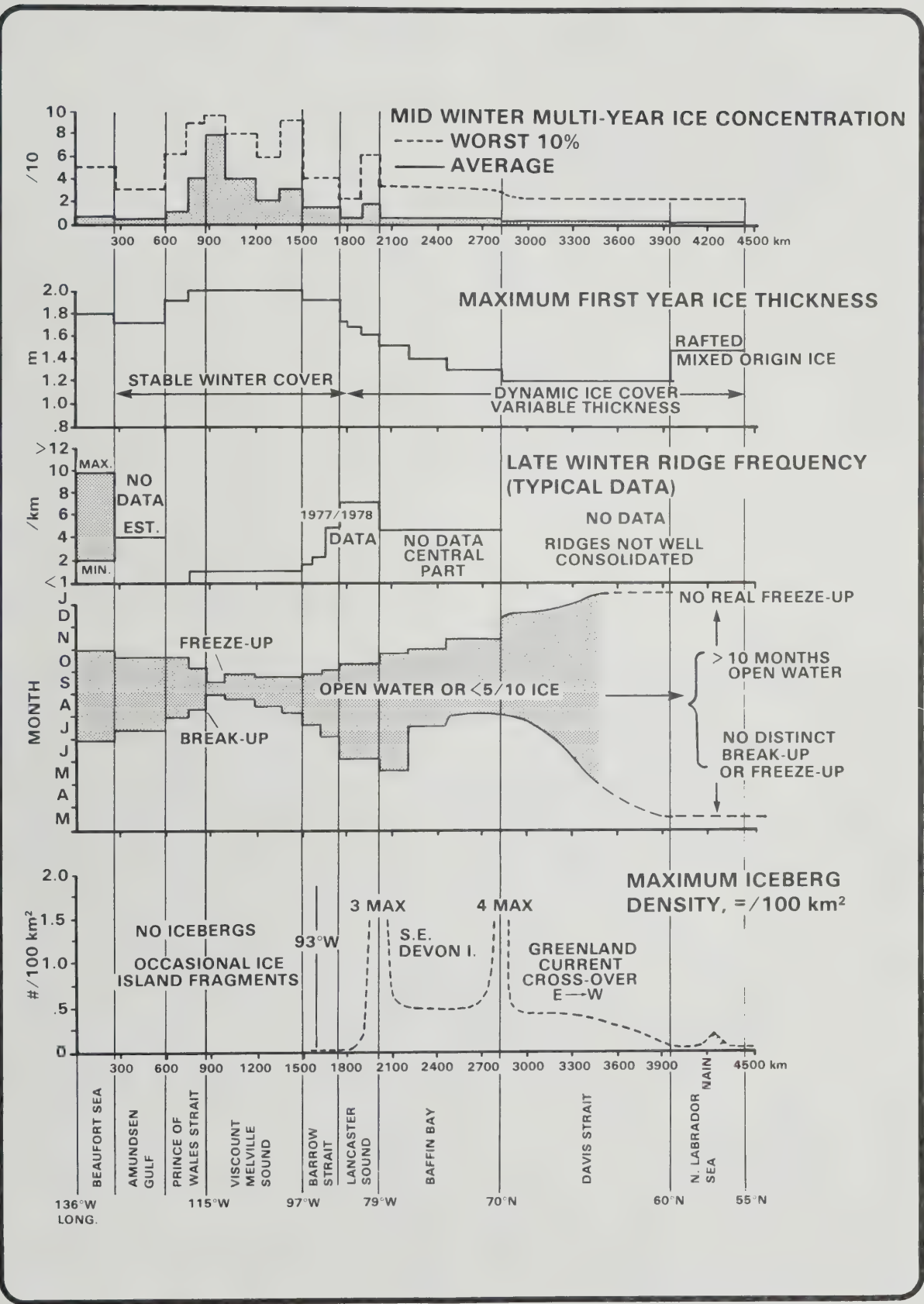


**PLATE 4.1.4:** *Larger multi-year ice features usually originate from the polar pack, break away and drift through the drilling area.*



**PLATE 4.1.5:** Ice Island "T3" broke off from the Ellesmere Island ice cap many years ago and has been recorded in the Beaufort Sea region on 2 occasions. These are the largest ice features which can be present and likely will set the design criterion for production platform design.

FIGURE 4.1.3: General summary of ice conditions from the Beaufort Sea through the Northwest Passage.



(c) Physical Research Relating to Beaufort Sea Development

The major design criteria issues relating to offshore platforms for Beaufort Sea development are summarized in Table 4.1.2.

Research in the above categories has been underway for over a decade to support Beaufort Sea operations. Most of the work has been conducted by Canadian engineers and scientists who have now among them, many of the world's experts in these fields.

Currently, Dome's internal research effort in these topics amounts to about 20 man-years per annum. Additional work is carried out through the use of Canadian consultants, universities and research institutes. Furthermore, the extensive exploration activities have provided essential support for research, and has led to a greatly improved understanding of the environment and the issues. In addition, since 1970 the Arctic Petroleum Operator's Association (APOA) has provided a vehicle for joint industry research on Arctic problems. To date almost 200 projects have been completed at a total cost of over \$40 million. Some examples of the work carried out follow.

(i) Ice Interaction and Research

When ice moves against a structure, it exerts a force. The structure has to be designed to resist the maximum ice force which can occur during the life of the structure. The magnitude of this force is governed by factors such as the local ice strength and thickness immediately in front of the structure, or by the available driving force in the surrounding pack ice (Figure 4.1.4).

Ice will normally fail in bending against a sloping structure at lower forces than in crushing against a vertical-sided structure. However, for a structure which is wide relative to the ice thickness, the ice clearing forces may become so high as to negate the advantages of the sloping geometry. In fact the ice may not clear at all around a wide structure,

leading to the creation of a rubble field as is usually seen around artificial islands in the Beaufort Sea. In this situation the oncoming ice acts on the outside of the refrozen rubble and the structural shape becomes irrelevant. Ice strength which governs ice forces is a complex issue that has taxed the ability of scientists and engineers for several decades. The issue is complicated by the fact that ice is a difficult engineering material to deal with. Since it is a material close to its melting point, it exhibits "creep," and its deformation characteristics are sensitive to temperature. Ice is also a brittle material when loaded quickly, but ductile at slower loading rates; thus its strength is sensitive to loading rate or strain rate. Ice also has a varied and anisotropic crystal structure which also influences its strength. Finally, ice is a natural material containing many cracks and flaws; their presence leads to lower strength with increases in the volume of ice being loaded.

From a scientific viewpoint there are still many gaps in our knowledge of ice strength, however much significant research has been conducted during the past decade. From a pragmatic engineering viewpoint, sufficient understanding now exists to safely predict ice forces on offshore Arctic platforms. In this respect it should be noted that small-scale measurements of ice strength generally yield higher values than occur in the field on a larger scale. Experience to date with artificial islands in the Beaufort Sea indicates that ice force predictions determined from small-scale tests and narrow structures are higher than those measured on relatively wide structures, such as artificial islands.

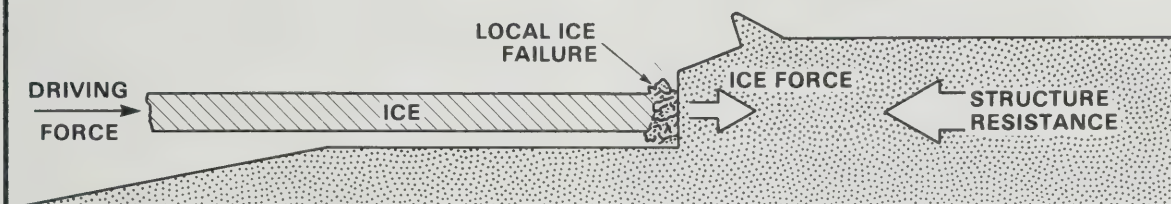
The ice forces for design of deeper-water Beaufort Sea structures are governed by extreme ice features such as the rare ice island, multi-year hummock fields and large, thick multi-year floes. A methodology has recently been developed which recognizes the varied stages of interaction of such features with offshore platforms.

In the initial stage of interaction of such large ice masses, the penetration into the structure is governed by the kinetic energy of the ice feature. At this point in our knowledge the best approach to stop a large ice feature appears to be to

<b>ICE INTERACTION WITH STRUCTURES</b>	<ul style="list-style-type: none"> <li>- ICE FORCES</li> <li>- ICE RIDE UP</li> <li>- ICE RUBBLE FIELDS</li> </ul>
<b>WAVES AND CURRENTS</b>	<ul style="list-style-type: none"> <li>- EXTREMES</li> <li>- EROSION PROTECTION</li> </ul>
<b>EARTHQUAKES</b>	<ul style="list-style-type: none"> <li>- MAGNITUDES</li> <li>- LIQUIFACTION</li> </ul>
<b>GEOTECHNICAL</b>	<ul style="list-style-type: none"> <li>- BORROW MATERIALS FOR ISLAND CONSTRUCTION</li> <li>- FOUNDATION CONDITIONS</li> <li>- ISLAND STRENGTHS</li> <li>- SEA FLOOR ICE SCOURING</li> </ul>

**TABLE 4.1.2:** Major design criteria issues for Arctic offshore development.

## NATURE OF ICE FORCES



- ICE MOVES AGAINST STRUCTURE
- ICE FORCE GOVERNED BY  
ICE STRENGTH OR DRIVING FORCE
- STRUCTURE RESISTANCE  $\gg$  ICE FORCE

**FIGURE 4.1.4:** Nature of ice forces interacting with a man-made structure.



**PLATE 4.1.6:** Multi-year hummock fields are thick consolidated masses of ice. Moving down from the polar pack they may cover an area of several square miles with a total thickness of perhaps 15 metres.

design a structure with a protective sand berm below the water line. The sand berm has to be large enough to stop the large ice feature before it penetrates sufficiently to cause catastrophic damage. In engineering terminology, the work done in deforming the sand berm and lifting the front end of the ice feature has to balance the initial kinetic energy of the ice feature, plus the work done by the external forces during the slowing down process. The external forces are wind drag, current drag and ridge-building forces from the surrounding pack ice, if present. This approach indicates that it is practically possible to stop a large ice feature such as a large ice island (10 km by 10 km by 50 m thick) before it reaches the central core of an artificial production island if a protective subsea berm is provided.

After the ice feature has been brought to rest, the ice forces are limited by the driving forces on the large ice feature. These ice forces can also be comfortably resisted by typical production platform designs. Thinner ice features which clear the berm will generate forces in the waterline portion, which can be calculated, although in some cases there may not be sufficient energy and driving force to cause full envelopment of the structure.

Verification of the physics of these interaction models are underway. The two main areas of investigation are the ice/soil deformation process and large-scale crushing strengths of multi-year ice.

The above models can be applied deterministically or sta-

tistically, the latter being a more valid engineering approach. The statistical approach recognizes firstly that there is an extremely low probability that a large ice feature will collide with a fixed point in the Beaufort Sea; secondly, that even if it does, it may not be moving at maximum velocity nor subject to maximum levels of driving force from wind, currents and pack ice. One can then consider the maximum probable ice feature which may interact with a structure during its lifetime and base the design criteria on this event.

To quantify the statistical approach, a probability model has been developed using the "Monte Carlo" approach, which integrates statistics for collision, floe sizes, ice thickness, velocity and driving forces. By simulating thousands of years of ice movement past a structure of particular geometry, statistical ice loads are generated, representing the selected risk levels (or return periods). From this kind of analysis the maximum probable ice feature can be selected and iceloads calculated. This ice feature is then used to conduct sensitivity analyses for various structural geometries to determine the optimum geometry for a particular structural concept. Ice research, which has led to our present high level of knowledge of ice forces, began in Canada in 1969 with large-scale ice crushing tests conducted in situ in the Beaufort Sea. These tests were followed by extensive laboratory studies of ice and model testing. In 1973, Esso constructed the world's largest ice test basin and this has been used every winter since then to evaluate ice forces and ice ride-up resistant designs; Dome



**PLATE 4.1.7:** Esso's ice test tank basin is the site of many important ice-related research programs, including studies of how ice interacts with model offshore structures as illustrated here.

has participated in much of this research through APOA. In parallel with these ice mechanics studies, field programs were conducted to better quantify ice conditions in the Beaufort Sea. These projects measured ice movements, ice ridge frequencies and thicknesses, and examined extreme ice features such as ice islands and thick multi-year ridges. From 1972 onwards, artificial islands constructed for exploratory drilling were monitored to study ice interaction patterns, ice pressures and geotechnical stability. This work has culminated in the extensive research program currently underway at the Tarsiut Island.

The Tarsiut Island is unique in many ways and better suited to a research program than previous islands. At 22 m (75 ft) it is at the most exposed location yet for an artificial island in the Beaufort Sea. It is in the moving ice zone for a greater period of the winter, and the ice conditions are more representative of deep water production locations. The concrete caissons at the waterline represent the first application of a caisson retained island and they are ideally suited for instrumentation to measure ice forces.

The scope of the Tarsiut Island research is outlined in Table 4.1.3. At a total cost of around \$7 million, the

program is the most comprehensive yet implemented on an Arctic offshore structure. An inventory of sensors installed at the Tarsiut Island is provided in Table 4.1.4 for reference. The ice pressure sensors are of new design; they were developed by Canadian consultants and Dome, and are among the most advanced in the world today.

We regard the Tarsiut experience as an extremely important and successful milestone in Beaufort Sea Development. First, it has demonstrated the feasibility of new construction technology (steeper berm slopes and caissons) which result in faster construction and less fill. Second, the ice force measurements will be used to calibrate predictions and confirm production island design criteria. Third, geotechnical measurements are confirming our predictions of island response under load, settlement and well-bore stability. Finally, monitoring of erosion under wave attack will enable us to predict maintenance and protection requirements against waves for production islands.

In normal years, offshore platforms in the southern Beaufort Sea are subject only to first year ice having a maximum thickness of about 2 m (6.5 ft). In more extreme situations the polar pack, consisting of multi-year ice, 4-5 m thick on

BEAUFORT SEA DEVELOPMENT	
RELATED RESEARCH	
SCOPE OF TARSIUOT RESEARCH	
CONSTRUCTION MONITORING	<ul style="list-style-type: none"> <li>- PLACEMENT OF 1:5 SLOPES</li> <li>- PLACEMENT OF CAISSONS</li> <li>- EQUIPMENT PERFORMANCES</li> </ul>
GEOTECHNICAL	<ul style="list-style-type: none"> <li>- SOIL RESPONSE DURING CONSTRUCTION</li> <li>- RESPONSE TO GRAVITY AND ICE LOADS</li> <li>- IN-SITU FILL PROPERTIES</li> </ul>
ICE INTERACTION	<ul style="list-style-type: none"> <li>- ICE FORCES ON CAISSONS</li> <li>- GENERAL PATTERN OF ICE INTERACTIONS</li> </ul>
OCEANOGRAPHIC	<ul style="list-style-type: none"> <li>- MEASUREMENTS OF WAVES AND CURRENTS</li> <li>- EROSION MONITORING</li> </ul>
OTHER PROGRAMS	<ul style="list-style-type: none"> <li>- WELLBORE INSTRUMENTATION</li> <li>- DEEP CORE</li> <li>- SEISMICITY MEASUREMENTS</li> <li>- REMOTE SENSING BASE</li> </ul>

TABLE 4.1.3: Scope of the Tarsiut Island research program.

## TARSIUT ISLAND RESEARCH INVENTORY OF SENSORS

### ICE FORCES

- FRAMES OF NORTH AND EAST CAISSONS ARE STRAIN GAUGED (TOTAL OF 274 GAUGES)
- 23 CIRCULAR PRESSURE PANELS 1 m DIAMETER ON NORTH CAISSON
- 4 FALSE-FRONT PANELS 4×4 m ON EAST CAISSON
- 20 PORTABLE PRESSURE PANELS INSTALLED IN RUBBLE FIELD

### ISLAND RESPONSE

- EXTENSOMETERS BETWEEN CAISSON AT CORNERS
- 5 IN-PLACE INCLINOMETER STRINGS FROM ISLAND SURFACE TO SEA FLOOR
- 2 VERTICAL EXTENSOMETERS (FOR SETTLEMENT)
- 3 SEISMIC ACCELEROMETERS
- 52 SOIL PRESSURE CELLS ON EAST CAISSON
- 23 PIEZOMETERS
- 13 TILTMETERS ON EAST CAISSON
- THERMISTORS

**TABLE 4.1.4:** *Tarsiut Island research inventory of sensors.*



**PLATE 4.1.8:** *Tarsiut, the newest and deepest man-made island in the Beaufort, sits on the edge of the mobile shear zone. Complete with a million dollar research lab, Tarsiut will enable scientists to monitor ice forces and foundation stability on a year round basis. The white spots in the sides of the caissons shown above mark the locations of some of the sensors.*

average can invade the area. Worst ice conditions for design are based, therefore, on multi-year ice rather than first year ice. The Tarsiut island is unlikely to see multi-year ice in the one or two years of its existence as an exploration island. Dome has recognized this and looked to other means of verifying multi-year ice loads on structures.

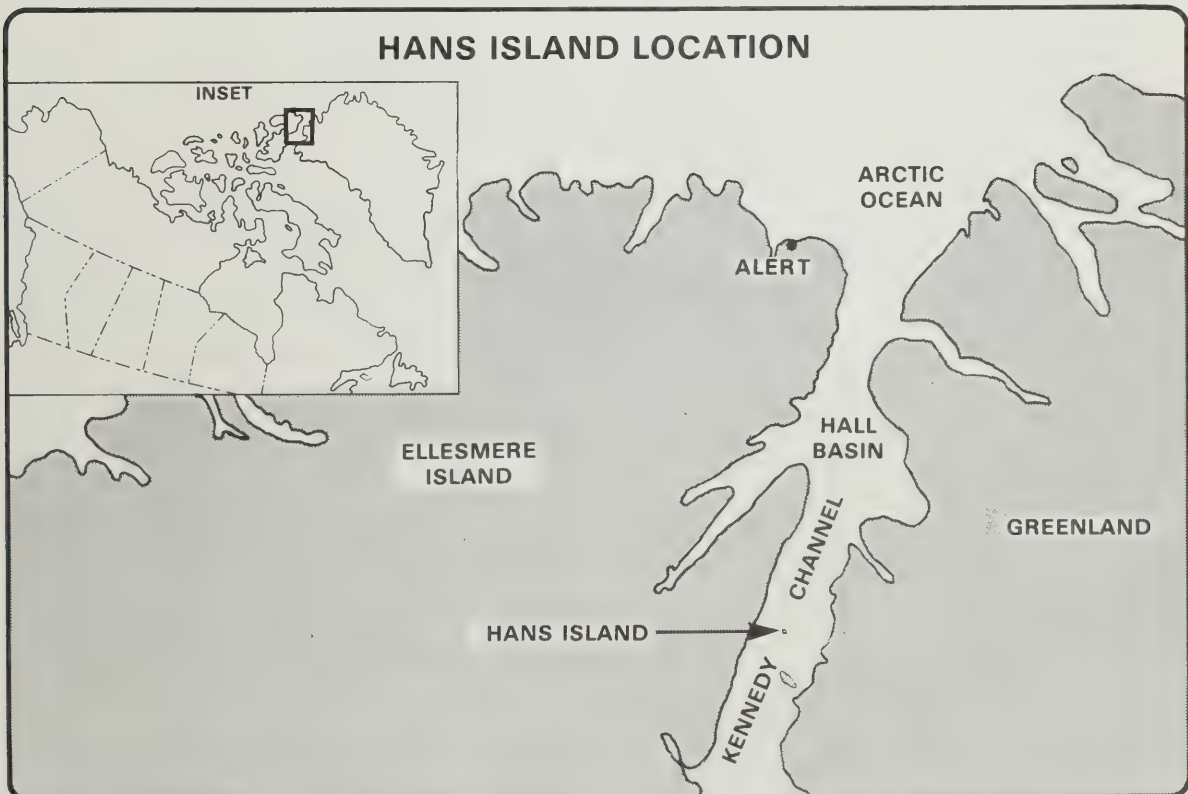
In 1980 Dome researchers searched for a natural island against which large multi-year ice floes collide regularly. Hans Island in the High Arctic situated in the Kennedy Channel between Greenland and Ellesmere Island was selected for this study (Figure 4.1.5). Each summer when the ice breaks up, large multi-year ice floes several km across move down the channel and collide with the small rocky island which is less than one km across. In 1980 and again in 1981, Dome researchers spent several weeks on this uninhabited island studying these ice interactions and taking measurements. By measuring the deceleration of the large floes as they were stopped by the island, and by recording floe size, and thickness, the ice forces acting on the floe (and hence the island) were derived. These measurements were the first ever made of the ice forces exerted by large, thick multi-year ice. The interactions simulate very closely, those that may occur in the Beaufort Sea for this type of feature. The measurements made at Han's Island, therefore, add considerable confidence to our designs for production platforms.

## (ii) Typical Production Island Configurations

A production island in 60 m of water can simply be an extrapolation of the Tarsiut design. The research on ice forces which have been described convinces us that such a design can withstand the ice forces, even from very extreme ice features. One can consider the lower slopes of the island to be a protective berm which will absorb the impact of the large thick ice features such as the rare ice island or thick multi-year floe. The upper part of the island can be designed for thinner ice failing directly against the caissons.

There are many variations on the production island, but all incorporate an underwater berm to protect against extreme ice features. The central core of the island can be replaced by a prefabricated concrete or steel structure on which all the production facilities would be built. Alternatively, a large concrete gravity structure might be placed directly on the sea floor and then surrounded by a protective berm.

Another alternative would be to create a large offshore atoll which could also serve as a protected harbour for tankers. Such a structure would also be able to resist the extreme ice features.



**FIGURE 4.1.5:** Location map of Hans Island in the High Arctic.



**PLATE 4.1.9:** As can be seen from this aerial view, Hans Island is a rugged piece of High Arctic terrain, with very little vegetation. The steep slopes form a buttress against the moving ice coming down the Kennedy Channel, with the peak of the island being about 200 metres above the water surface.

### (iii) Waves

The presence of ice in the Arctic Ocean limits the fetch over which the winds can generate waves. Consequently waves in the Beaufort Sea are less severe than in other large seas and oceans. Industry and Government have been measuring and studying waves in the Beaufort Sea since the early 1970's. Wave data from wavebuoys supplied by the government's Marine Environmental Data Service have been obtained every summer since 1975. In addition, wave hindcast studies have been conducted to extend the measured data over a longer statistical base.

Since wave heights in the Beaufort Sea are very low compared to other areas such as the North Sea, where structures are designed to withstand 30 m waves, wave action in the Beaufort does not present a problem of structural safety once a platform is complete. Rather, it is of importance in designing erosion protection. Deep water production platforms in the Beaufort Sea are likely to be artificial islands topped with a prefabricated caisson structure. They will be used to penetrate through the zone of wave action and will be erosion resistant. In the case of the bermed or atoll structure the subsea berm will extend to about 10 metres below the water surface, and thus will be unaffected by wave action. In the future, it is possible that caissons will also be used commonly in the construction of shallow water islands, in addition to more conventional methods of

slope protection such as rip-rap, sandbags, chain-link fencing and filter cloth.

### (iv) Earthquakes

The Beaufort Sea is seismically active, but the risk is much lower than in, for example, California or the Gulf of Alaska. However, until recently the data base was quite limited. At the same time, sand islands may be susceptible to liquefaction under a severe earthquake, although it can be prevented by the use of techniques such as freezing or densification.

This issue is the subject of ongoing research. A preliminary seismic exposure study has recently been completed. In addition, Dome on behalf of industry and in conjunction with the Division of Seismology of the Department of Energy, Mines and Resources, has installed four additional seismographic stations along the Beaufort Sea Coast. Also in conjunction with EMR, ocean bottom seismographs were installed for a short time during the summer of 1981 to measure any ocean floor accelerations caused by earthquakes.

As the new data on earthquake measurements become available, they will be analyzed, a more detailed and reliable seismic/tectonic model developed, and design criteria will be revised, if necessary.

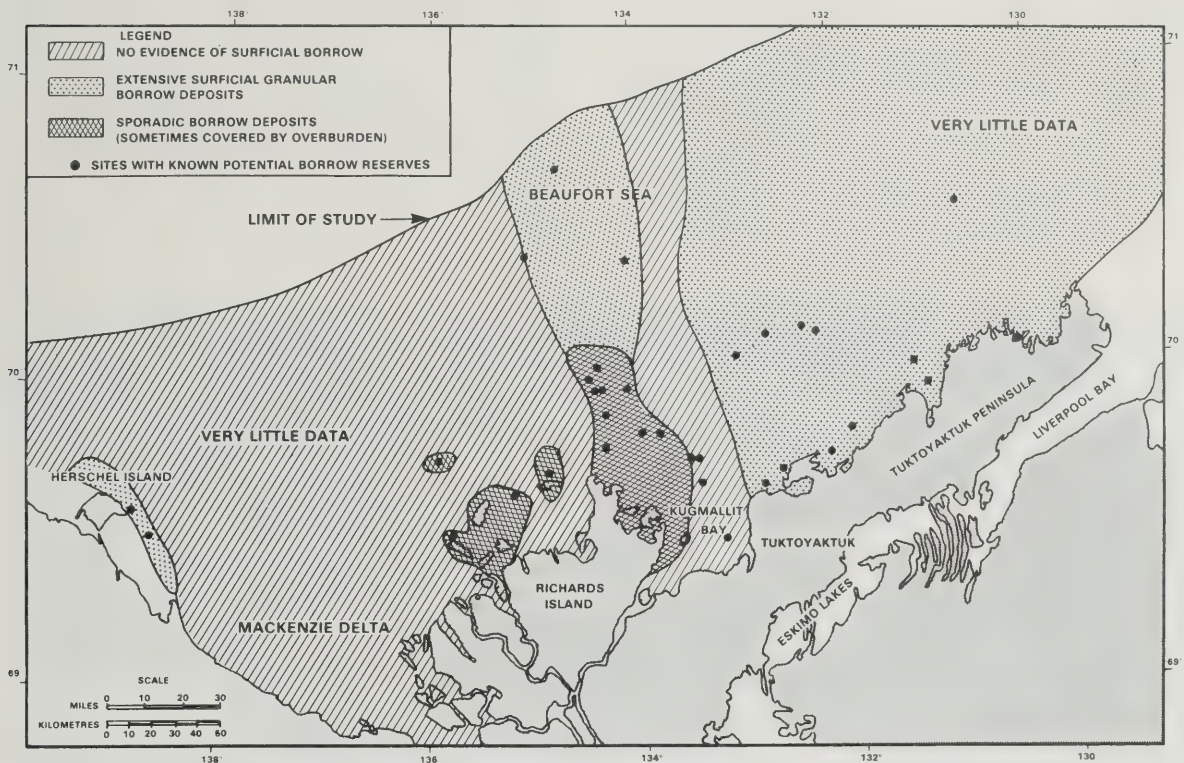
#### (v) Geotechnical Investigations

Since the early 1970's, industry has been accumulating information on the soil conditions beneath the Beaufort Sea floor. To date over 500 cores have been taken, and over 20,000 km of shallow seismic surveys have been conducted. A good general knowledge of the surficial geology of the southern Beaufort has now been developed and specific foundation conditions have been determined at island locations. Much of the work has been aimed at delineating sand and gravel deposits for island construction purposes. This work has been quite successful and considerable volumes of granular material (more than enough for likely production scenarios) have been located, especially east of Kugmallit Bay (Figure 4.1.6).

ing. The results are being used to determine optimum routes and trenching depths for offshore pipelines.

## 4.2 REMOTE SENSING

Safe and efficient tanker navigation in Arctic and East Coast waters will be supported by a system known as REMSCAN which is being developed within Dome. The acronym REMSCAN stands for Remote Sensing, Communications and Navigation. In addition to these functions, however, it will provide support in several other areas including ice, ocean and weather forecasting and route optimization. In short, REMSCAN is a system which will acquire, process, disseminate and display the informa-



**FIGURE 4.1.6:** Granular material survey results of the Beaufort Sea. Sufficient borrow material exists to satisfy all production scenario demands.

Offshore permafrost exists in the Beaufort Sea and its extent has been mapped by drilling and shallow seismic surveys. As long as it is properly accounted for in well-bore design, its possible degradation due to production of warm oil is not expected to cause problems. Solutions to potential well-bore damage have been found for production through permafrost on the North Slope of Alaska and similar solutions will be applied to the Beaufort.

A great deal of research on ice scouring of the sea floor has been done during the last decade by both Government and Industry. Side-scan sonar mapping and echo-sounding have provided data on the frequency and depth of scour-

tion required for making decisions which will assist in providing safe and efficient tanker transport.

The information generated will appear in several forms and will serve different needs at various locations. One form for example, would be a picture or map, available to the ship's master, displaying ice conditions near the vessel, identifying obstacles, indicating a route of least resistance and providing continuous update. Another form of information would be the predicted ice conditions along the projected route. This would be provided to the ship and to the operations centre, would be displayed as a map and would be updated on a time scale related to ship's speed

and other factors. Other types of information generated by REMSCAN range from ship's position through environmental data; from voice communications to route planning strategies.

As described in Section 5.0 of this submission, the tanker strength will allow it to survive a head-on impact with an iceberg of a specified size. However, REMSCAN will enable the tanker, with a high degree of accuracy, to avoid such impacts. In this respect, REMSCAN is a safety system independent of but complementary to the tanker design. Similarly, the tanker is designed for transit of virtually all ice types. REMSCAN will provide a route planning capability so that zones of heavy ice may be avoided, thus optimizing transit time.

In the following discussion, the components of REMSCAN are described.

#### (a) Ice Surveillance and the Role of Remote Sensing Technology

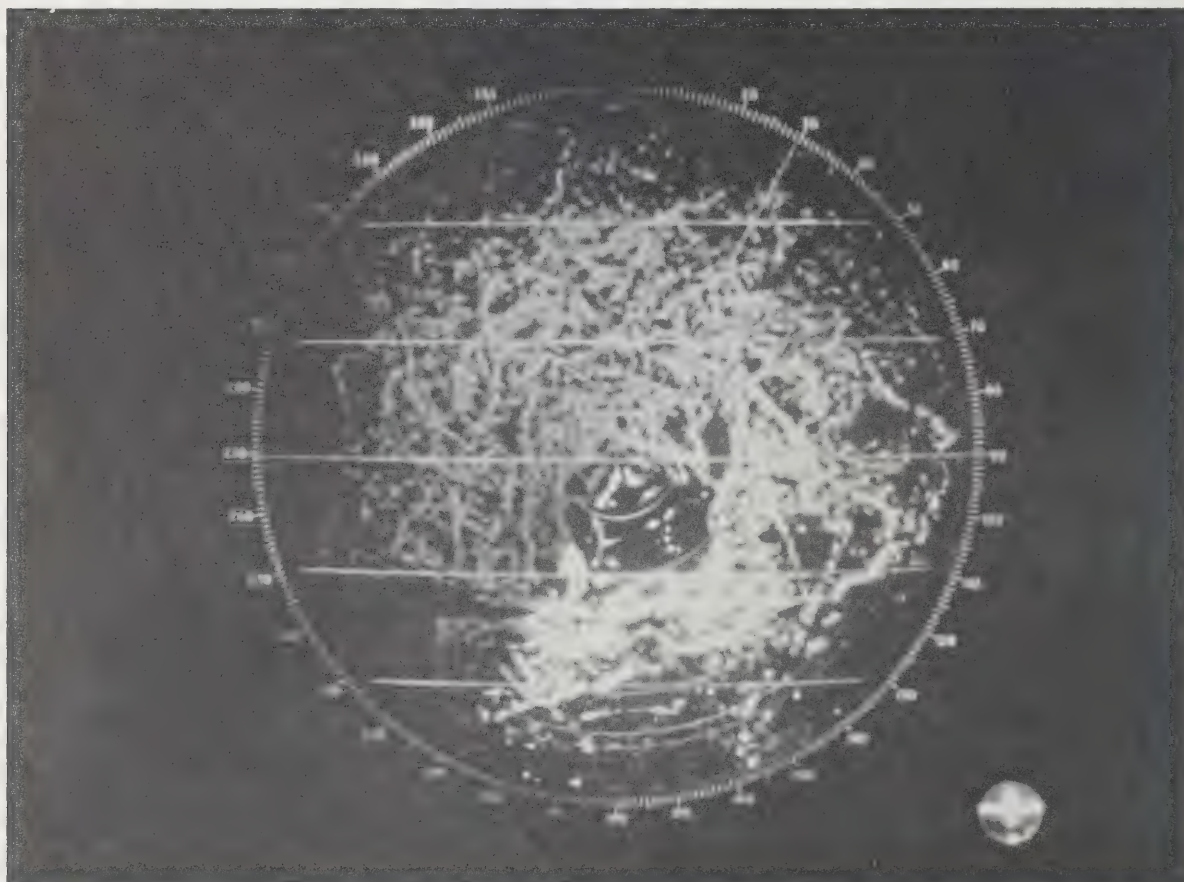
As the name implies, remote sensing technology serves to extend our sensory capabilities. The many techniques and forms of remote sensing provide a means not only to extend the distance that we can 'see' but also to receive

different types of information from the 'target' of interest. Furthermore, some forms of remote sensing lend themselves to day/night or all weather applications. Other considerations relate to the kind of 'platform' in which the sensor is carried, the frequency of coverage, the processing of the data and the means by which the data are transmitted to the users.

Three levels of remote sensing support are planned. These levels, related to application, are referred to as *strategic*, *tactical* and *close-tactical* support.

*Strategic* support will provide the 'global' picture of ice and environmental conditions in order to make predictions, projections and plans over time scales several days in advance of tanker arrival/departure. Close-tactical surveillance, by contrast, refers to ice conditions immediately in the vicinity of the tanker, the objective being to detect icebergs or other ice forms larger than some mass (e.g. 100,000 tonnes) within a given critical range (e.g. 15 km) of the vessel. This will provide sufficient response time to allow the ship to avoid the obstacle given that the tanker may be travelling up to 1 km in 1.5 minutes (approximately 20 knots).

Tactical remote sensing will provide a picture of ice condi-



**PLATE 4.2.1:** Radar imagery will assist navigators in identifying ice features above the frozen sea surface, which in combination with other information, will allow selection of the best possible routes for shipping.

tions along a broad corridor in advance of the tanker over a region that typically covers one day's sailing time. This information will enable the vessel to steer toward open leads, away from heavy ice or iceberg concentrations, and generally to provide advance warning of conditions to be encountered within the next few hours of the voyage. Not only does the geographic coverage differ for these three levels of surveillance, but so does the time frame covered.

Close-tactical surveillance will have 'local' but continuous coverage; tactical will provide 'regional scale' coverage typically repeated daily (depending on ice mobility and other factors); and the strategic picture will only need to be updated over several days.

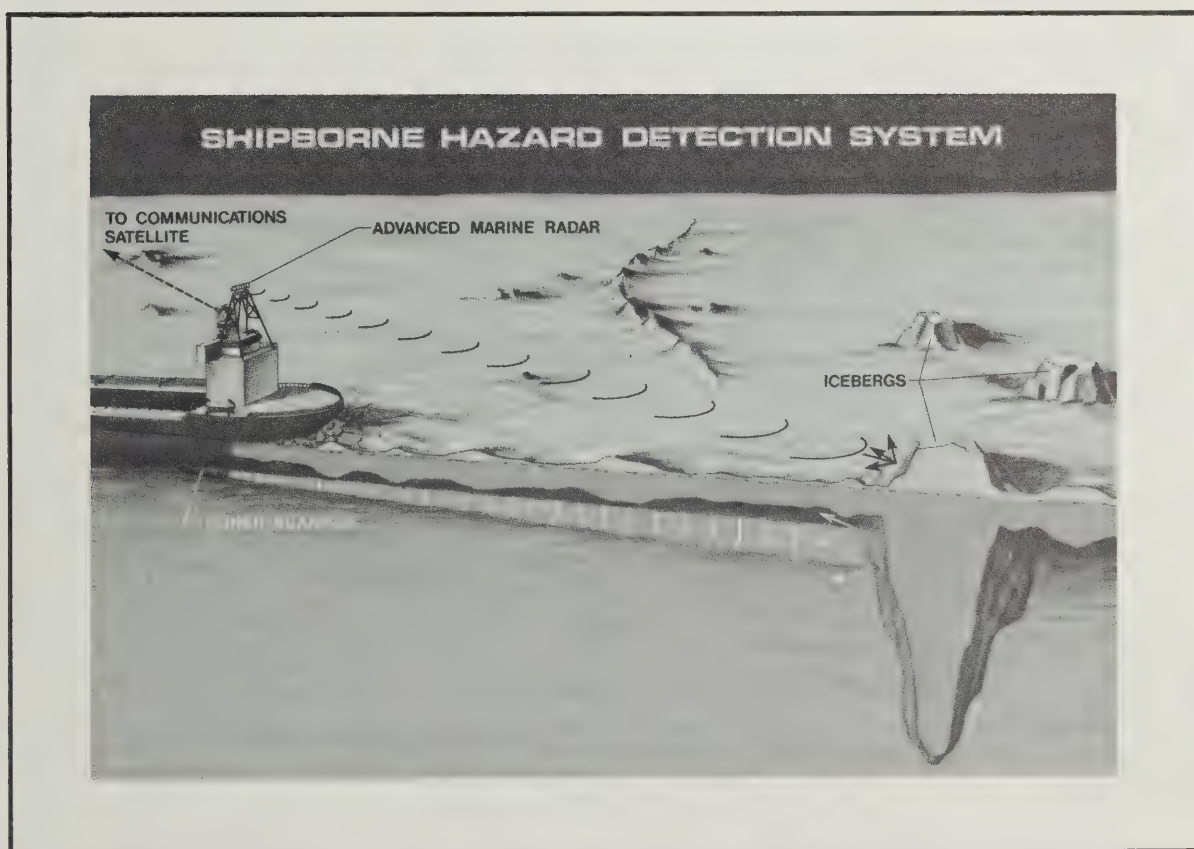
To meet these requirements a combination of technical solutions will be applied. Some of these are already in existence, others will require further R&D effort.

For close-tactical support under all weather conditions, shipboard radar will be a prime component. However, experience with conventional marine radars has indicated limitations in their detection capability, depending upon the nature of the 'target,' the sea state, and the weather conditions. The concept of an Advanced Marine Radar is being examined, with research and development programs being directed toward producing a radar system tailored

for close-tactical ice surveillance. In addition to designing this radar specially for that function, particular attention will be devoted to enhancing the radar signal data by an on-board computer system. The radar display screen will similarly be optimized for the close-tactical surveillance function.

In addition to radar, the Arctic Tanker will likely have several other kinds of sensors not commonly seen on non-military vessels. The exact combination of technologies to be used will be determined by further study. At present the most promising include sonar scanners which bounce sound waves off the submerged part of ice floes, passive microwave or thermal infra-red scanners which can detect small temperature variations, and low light level optical devices.

The objective is to have better, more accurate real-time information through a combination of complementary technical systems. In conditions where radar performance may be degraded, a thermal or sonar scanner, for example, would recover the lost performance. The combined data from these remote sensing systems will be integrated and displayed on a CRT (cathode ray tube) screen, giving the captain on the bridge a moving map of conditions in front of the tanker.



**PLATE 4.2.2:** Shipboard radar will feed up-to-the-minute information on ice conditions above and below water directly into each ship's processing centre, ensuring that every vessel travels the best possible route.

A common factor among these sensors is that they are shipborne systems, thus ensuring that the tanker has a stand-alone capability should other support be interrupted.

As an extension of the shipborne surveillance capability, a number of other possibilities are being examined, including helicopter-borne ice thickness sounding systems, tethered balloon-borne imaging radar and sensor-carrying remotely piloted vehicles (RPV's). These exotic sounding systems are in various stages of development and could form a component of the ship-based system of the future.

Longer range detection of ice conditions will use aircraft and satellites. In particular, all weather, day/night tactical support will be provided by high altitude aircraft carrying synthetic aperture radar (SAR). The capability of airborne SAR for producing high resolution, photo-like images of ice has been demonstrated in the Beaufort Sea over the past three years, and plans are underway for the development of a lightweight system specifically designed for operational use.

The potential of satellite SAR for mapping ice was demonstrated in the summer of 1978 by the short-lived experimental satellite called SEASAT A. By the late 1980's Canada is expected to have an operational SAR satellite capable of imaging the ice in the Northwest Passage and

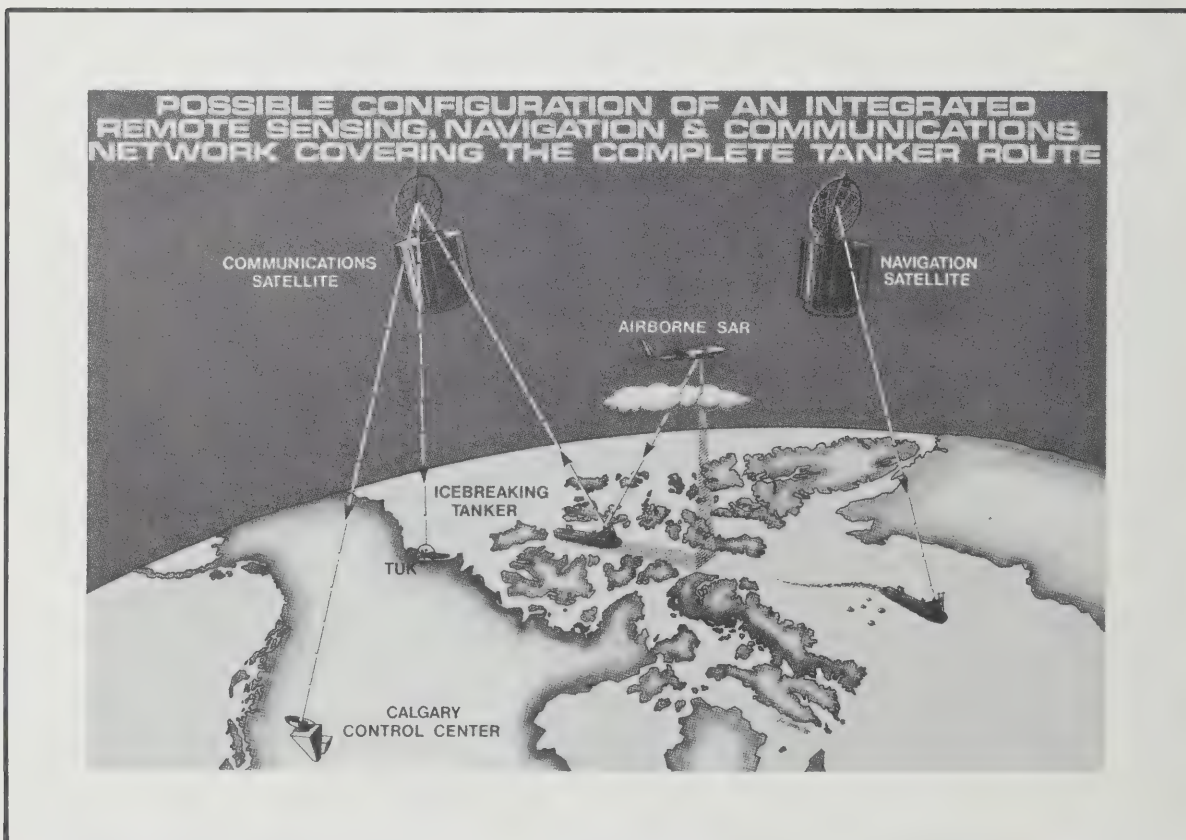
transmitting the information to an "Ice Central" facility for dissemination to tankers and other users. Once satellite SAR becomes operational it will probably displace at least part of the airborne SAR patrol, although it is likely that the virtues of aircraft flexibility will make this method of surveillance important for the foreseeable future.

The requirements for strategic support — the 'big picture' — will be met at least initially from a composite of sources including airborne SAR and other radars, and by satellites producing 'visual' and IR spectrum images such as those of today's Landsat. In later years it is possible that satellite SAR will satisfy the majority of these requirements.

#### (b) Ice Predictive Capability

During the course of the seasons the ice cover over much of the route is mobile; its motion and other dynamic characteristics being determined by winds and currents. The degree to which this may affect transit speeds will depend very much on the region, the time of year and the type of ice.

In circumstances where ice conditions are expected to change significantly between surveillance 'updates,' ice forecasts will be provided. Thus tactical and strategic route plans will be based upon forecast ice conditions when the



**PLATE 4.2.3:** This artist's rendering illustrates how satellites, and airborne synthetic aperture radar, will provide the tactical and strategic forecasting necessary to operate Arctic tankers year-round through the Northwest Passage.

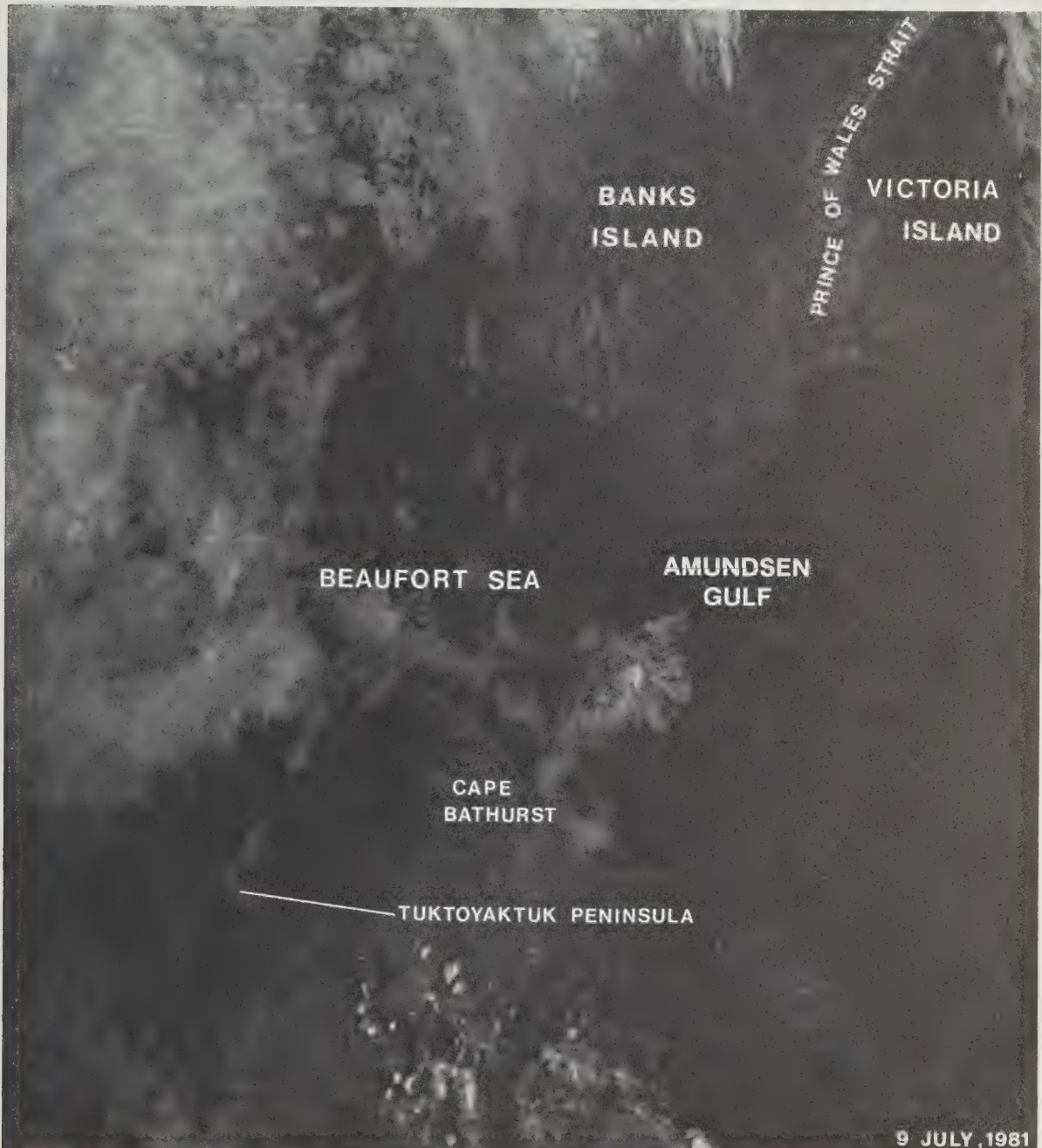
vessel arrives at a particular location, rather than on what these conditions were when the surveillance took place.

Development of ice forecast models for summer and winter ice conditions in the Beaufort Sea is well under way. Similar activities are taking place on the East Coast, where there is a need to predict iceberg motion. Because of the apparently erratic behaviour of icebergs, it may be necessary to increase the frequency of aircraft surveillance missions in the relevant areas.

#### (c) Positional Navigation

As in the case of remote sensing, a variety of requirements will be satisfied by a combination of technical solutions. Most of the technologies are either available now or well advanced in their development.

General navigation requirements can be satisfied by land-based low frequency radio positioning networks such as LORAN C which provide continuous location informa-



**PLATE 4.2.4:** For long range, strategic route selection tanker captains will receive an encompassing view of ice conditions in the Canadian Arctic, projected over several days in advance of sailing.



**PLATE 4.2.5:** Aircraft carrying high resolution, synthetic aperture radar (SAR), can photograph a corridor up to 80 kilometres wide in front of the Tanker, and then transmit the photographs to the bridge of the ship or elsewhere.



**PLATE 4.2.6:** This photo illustrates what a ship's captain sees on a typical CRT (cathode ray tube) screen presently in use on a supply vessel in the Beaufort. A similar system would be employed on the Arctic tanker. The left side shows the shoreline of McKinley Bay in the Beaufort, with the right, larger scale image showing the position of the ship in relation to a navigation corridor.

tion of suitably high precision. Alternatively, a shipborne inertial navigation system when combined with positional updates provided by the polar-orbiting, Transit navigation satellites provide a similar capability. These systems are in common use today.

The primary navigational tool of the late 1980's, however, is likely to be the 18 satellite Global Positioning System (also called NAVSTAR). This system, presently under development by the U.S. military, will be available for commercial use and will enable the Arctic tanker to know its position at all times to within about 200 metres. While maneuvering in confined spaces, passing through channels or when docking, the tanker will use short range radio positioning systems and/or radar as required. Radar reflectors or transponders placed in strategic locations where the tanker passes close to land will serve as independent checks on the prime navigation system. CRT displays, together with off-course warning devices will ensure that bridge personnel are well aware of the tanker situation at all times.

The tanker positions will be continuously monitored at the Operations Centre and relayed to the Canadian Coast Guard for Vessel Traffic Management purposes. One objective of this system will be to ensure that all vessels within the passage are adequately informed, monitored and equipped to avoid collision. The Federal Government Control Authority being established by the Department of Transport is discussed in Section 5.0 of this submission.

#### (d) Communications

An extensive communications network will be required for transmission of imagery, maps, data and voice information among the tankers and other information sources and users. It is probable that there will be at least two Operations Centres (perhaps Tuk Base and the East Coast terminal) and the Calgary Management Centre which will act as 'nodes' in the network. Additionally there will be external interfaces, with government (Ice Central, AES, CCG, etc.) and probably other industry members.

Satellite communications will likely form the primary link, although landline and other options will be examined both as alternatives and as backup.

Canada's Anik D communications satellite offers one possibility although it has not yet been optimized for marine/mobile communications. Other satellite options under consideration include Anik C and M-Sat, the latter a special purpose satellite being designed for mobile communications. Thus the problem of establishing the communications network is not one of technology — rather one of selecting the best choice among several options which will enable the requirements related to capacity, flexibility, access, reliability, growth potential and cost to be satisfied.

#### (e) Conclusion

REMSCAN will provide the support necessary to significantly increase the margins of safety and efficiency under which the Arctic tankers will operate. Most of the technologies are available commercially today or are in an advanced state of development. R&D effort will continue to be emphasized in certain areas — mainly remote sensing and ice forecast — to ensure that all requirements will be satisfied.

## 4.3 OIL SPILL RESEARCH

This part of the submission will briefly review the experiences of the industry in the field of oil spill research and countermeasures technology developments. This will be followed by a discussion of the risks associated with tanker transportation of oil in the Arctic and will elaborate on the prevention and countermeasure techniques available with respect to large oil spills from tankers. The environmental issues associated with such spills are addressed in the Environmental Research portion of the submission.

#### (a) Background

Since 1973 much research and development work has been carried out in Canada to understand and deal with major oil spills in Canada's Arctic. The first major undertaking was the Beaufort Sea Project, a \$12 million environmental assessment of proposed exploration drilling programs in the Beaufort Sea. One of the major issues addressed in this project was that of the fate and effects of spilled oil and countermeasure (cleanup) techniques available for dealing with subsea oil well blowouts. This prompted research and development projects by both industry and government. The purpose of these projects was to develop spill countermeasures for the Beaufort Sea and to ensure that appropriate equipment was available to respond to spills.

Close coordination and cooperation on these projects has been ensured by joint industry/government working groups set up by the Arctic Petroleum Operators Association (APOA) and Environment Canada's Arctic Marine Oil-spill Program (AMOP).

AMOP was set up in 1976 with a budget of \$7 million, to carry out research and to develop Arctic oil spill countermeasures. In 1980 the Canadian oil industry set up the Canadian Offshore Oilspill Research Association (COOSRA) to conduct and sponsor controlled oil spill experiments, equipment tests, dispersant tests and other related research in Canadian marine offshore areas. The total investment in Canadian Arctic spill research and development to date is approximately \$35 million. The results of this research and development and their application to actual spills are discussed in the following sections.

(b) Oil Spill Research and Countermeasures  
For the Arctic

A synopsis of the research programs and the resultant equipment and techniques for Arctic oil spill cleanup is given in the attached brochure entitled "Ice is Nice." The technology described in the brochure can be used to respond effectively to spills from tankers. Some of the more important systems include:

(i) Open Water Containment and Recovery

Oil spilled on water is contained by special floating booms and then recovered using skimmers (devices that pick the oil up off the water surface).

(ii) Fire Proof Boom

A unique technique for collecting and disposing of spilled oil is under development by Dome. A boom, constructed of stainless steel can contain the concentrate floating oil while it is burned in situ.

(iii) Response Barge

The Dome Response Barge, stationed at Tuktoyaktuk, is designed as a self contained open water cleanup system. Oil is directed to the skimmer by specially constructed Arctic

boom. Recovered oil is pumped to storage or processed for disposal by burning. The burner has a capacity of 5,000 BOPD.

(iv) Portable Burner

Dome has researched and developed a helicopter-portable flare burner. The system, consisting of a burner, a control panel and a generator, can be moved to any remote site to dispose of up to 500 BOPD containing up to 60% water.

(v) Air Deployable Igniters

Oil spilled in or under ice will appear in pools on the ice surface during the following melt period. Dome has developed a simple, effective igniter that can be dropped from helicopters to burn off oil on ice.

(c) Tanker Spills — Probability and Prevention

(i) The Nature of Tanker Accidents

Numerous studies and analyses of tanker accidents have concluded that at least 75% of them have been due to human operating errors.

In a recent study commissioned by Dome, one of the world's leading classification societies, Det Norske Veritas,



**PLATE 4.3.1:** Shoreline countermeasures equipment available to respond to oil spills in the Beaufort Sea include a large selection of booms and skimming devices.



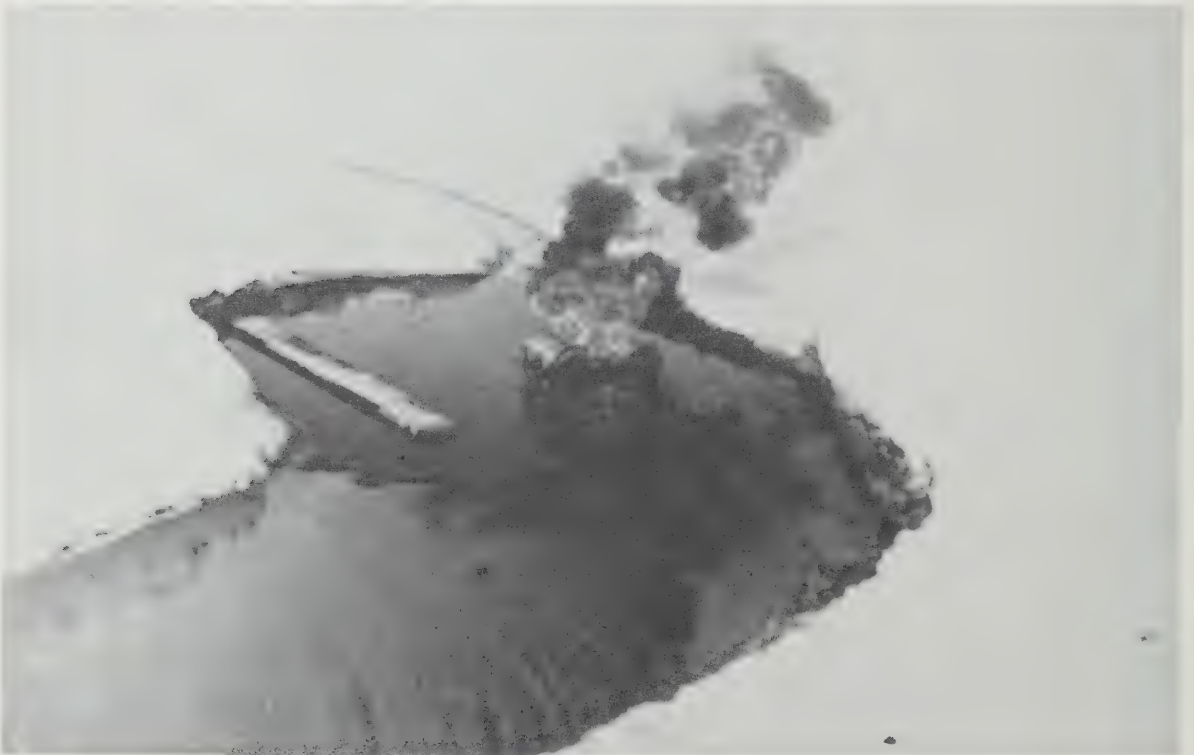
**PLATE 4.3.2:** As a result of the IXTOC experience, a unique fire-proof containment barrier has been researched and developed to the prototype stage by Dome. The purpose of this device is the containment of oil for in situ combustion in close proximity to the release point of a subsea blowout.



**PLATE 4.3.3:** One of the key systems for offshore clean-up is Dome's oil spill response barge equipped with large "Arctic booms" and a skimmer modified for Arctic conditions. After recovering the oil from the water surface, it can store and incinerate up to 5,000 barrels of oil per day.



**PLATE 4.3.4:** The SAACKE rotary cup heli-portable burner can burn up to 500 barrels per day of a 60% water-in-oil-emulsion. It can be used for shoreline clean-up operations and can also work from floating platforms such as barges and supply boats.



**PLATE 4.3.5:** Specially developed air deployable igniters are now available to allow oil spill cleanup crews to burn oil on ice or in confined leads by dropping these igniters from aircraft.

found that: of the 18 major tanker spills (between 1968 and 1978) analyzed in detail, 11 were the direct result of human action; three involved mechanical failures and could have been avoided by proper corrective action; the remaining four involved structural failures of which three occurred because the vessel was not being operated correctly. Only one accident was not caused by human action or inaction.

Figure 4.3.1 shows a distribution of tanker accident types resulting in spills greater than 180 m<sup>3</sup> between 1967 and 1978. The results are presented in terms of ship deadweight size ranges. Overall, 42% of the spills resulted from *groundings* and 23% were due to *collisions*. Groundings generally occur close to shore in good visibility and are caused by navigation or steering errors. Most collisions occur in poor visibility conditions in high traffic areas. Collisions are caused by misinterpreted “rules of the road,” poorly trained crews and a failure on the part of the ship’s masters to establish a passing agreement. The remaining 35% of the spills resulted from structural failures due to heavy weather, many of which could probably have been avoided by changes in course to reduce stress levels, explosions, fires and general breakdowns. The last three causes were directly related to the ship being in a neglected condition and operated by poorly trained personnel.

(ii) Independent Versus Oil Company

The human causes of tanker accidents can usually be

linked to the management policy of the ship’s owner. The owner is largely responsible for the quality of the crew and the maintenance and safety of the vessel. About 60% of the world’s tanker fleet is owned by independents, many of which are “One-Ship Limited” companies. The remaining 40% of the ships are owned by the oil industry. A recent study by the Netherlands Maritime Institute showed that oil company vessels have an accident rate approximately 1/7th that of the independents. This is not due to a difference in age or size of the vessels, since the average age of oil company vessels is close to the world average. The management and crewing of the vessel has inevitably been the deciding factor.

(iii) The Consequences of Tanker Accidents

According to statistics, less than half of all tanker accidents result in spills. As shown in Table 4.3.1, in 59% of the major spills, individual discharges were each less than 15,000 tons. The remaining 41% of the major spills accounted for 89% of the oil spilled worldwide by tankers. It has also been shown that older, smaller tankers are involved in the most accidents.

(d) The Arctic Tanker — Spill Prevention

One major result of the Det Norske Veritas study of past tanker spills was a list of recommendations for the design, outfitting and operation of an Arctic tanker. Implementa-

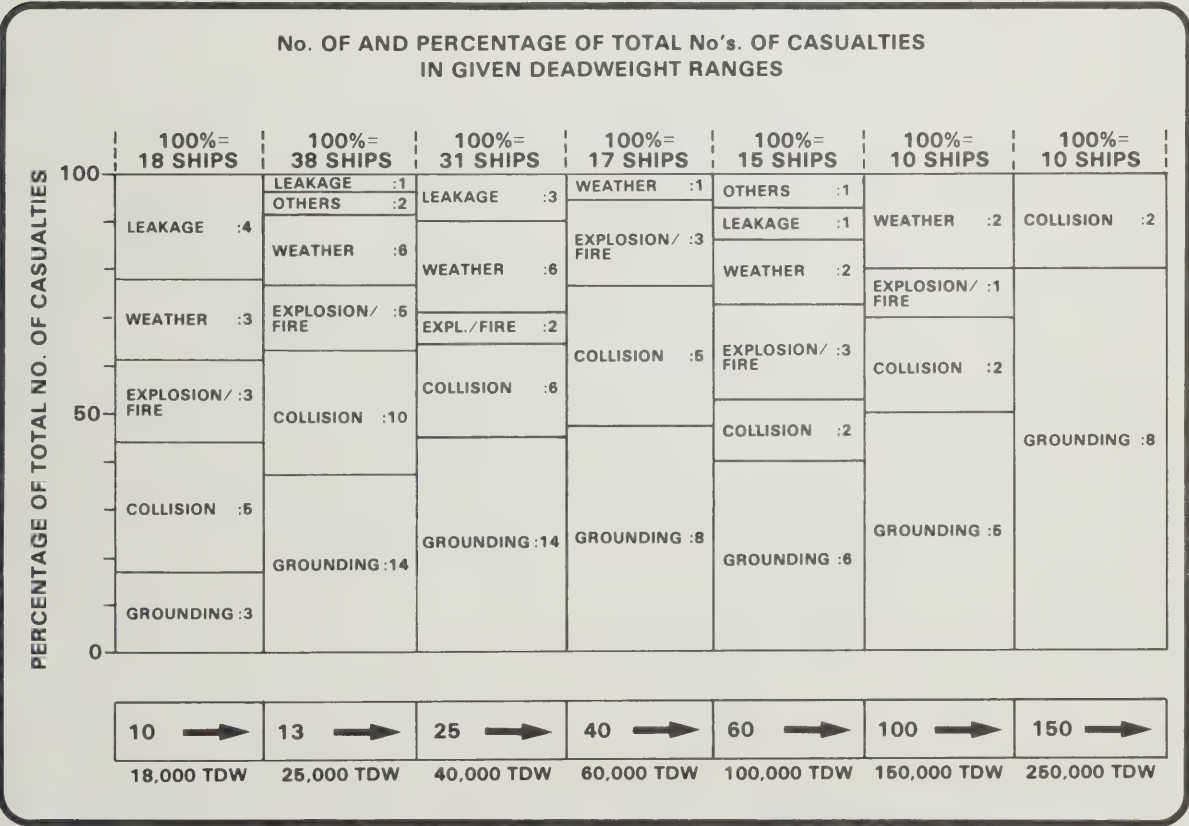


FIGURE 4.3.1: Distribution of the types of tanker accidents examined by Det Norske Veritas.

**No. OF SPILLS AND THEIR SIZES**  
**SIZE OF OILSPILL IS DENOTED 'S'**

SIZE RANGE OF OILSPILL	CASUALTIES REPORTED		SUM OF OILSPILLS RECORDED	
	No. OF	% OF TOTAL	TONS	% OF TOT. SPILL
200 T < S ≤ 1,000 T	17	21.8%	9,750 T	0.6%
1,000 T < S ≤ 2,000 T	5	6.4%	6,620 T	0.4%
2,000 T < S ≤ 5,000 T	13	16.7%	47,255 T	2.9%
5,000 T < S ≤ 15,000 T	11	14.1%	118,250 T	7.2%
15,000 T < S ≤ 30,000 T	10	24.3%	444,880 T	27.0%
30,000 T < S ≤ 50,000 T	6	7.7%	232,819 T	14.2%
50,000 T < S ≤ 100,000 T	4	5.1%	327,000 T	19.9%
S > 100,000 T	3	3.8%	457,000 T	27.8%

**TOTAL = 78**

**TOTAL = 1,643,574 TONS**

**FIGURE 4.3.1:** *Distribution of the types of tanker accidents examined by Det Norske Veritas.*

tion of the 36 recommendations has resulted in an Arctic tanker design that will minimize both the occurrence of accidents and the spillage of oil in the event of an accident. Some of the direct oil spill related safety features incorporated into the design of the Arctic tanker include:

- a double hull protecting the cargo tanks from the effects of collisions and groundings. The use of the between hull space for ballast eliminates the discharge of ballast water contaminated by oil as a source of pollution
- cargo transfer systems using deep well pumps and deck piping to eliminate the pump room and in-hull piping
- a unique oil containment and recovery system between hulls in the event of cargo tank damage due to grounding
- special re-floatation system in the event of hull rupture due to grounding

Details of these, and the more general safety features of the Arctic tanker are discussed in Section 5.0 of this submission.

#### (e) Arctic Tanker Risk Analysis

To obtain information on the spill safety of the Arctic tanker design, Dome commissioned a study in 1977 of the spill risks associated with the tanker, compared to conventional tankers operating in ice-free waters. The study identified those tanker features which would be more prone to causing accidents than others.

In 1981, the study was updated to consider the newer

design features. The 1981 risk analysis takes into account such items as stronger hull plating, dual propulsion and steering, deep well pumps, a compressed air system for floatation, hull stress monitoring and additional navigational equipment.

The most important findings derived from both the 1977 and 1981 work are summarized as follows:

- The Arctic tanker will operate with a spill risk estimated to be 120 to 160 times less than that of a conventional oil company tanker operating on a southern Canadian route.
- Much of the reduction in spill risk for the Arctic tanker is attributed to the vessel's double hull which is strengthened for icebreaking and which would provide much greater protection for cargo tanks in the event of a collision or grounding.
- The Arctic tanker's strong hull and stress monitoring systems reduce the risk of structural failures to a very low level.
- The Arctic tanker's combination of complete tank inerting (replacement of the oxygen in the cargo and ballast tanks with an inert gas) and the segregated ballast tanks greatly reduce the risk of a spill due to an explosion.
- The risk of a spill due to a collision with an iceberg and/or grounding is minimized by the Arctic tanker's sophisticated ice detection and prediction systems.

The results of the risk studies show that the Arctic tanker will be safer than conventional tankers. However, as the study of past incidents has shown, human error is closely

linked to accidents. In order to reduce human error, Dome will also ensure that the officers and crew are

- well trained and experienced;
- regularly exercised in classrooms and actual situations;
- exposed to emergency procedures using computer training simulators (as used for airline pilots); and
- alert on the job, through the provision of entertainment, recreation and regular shore leave.

In order to ensure that the tankers are always operated in a safe manner, regular and random maintenance procedures will be instituted, and operations and safety inspections of the ship will be carried out by the company. Furthermore, constant monitoring of the tanker operations will be provided by the control centre.

#### (f) Spill Response

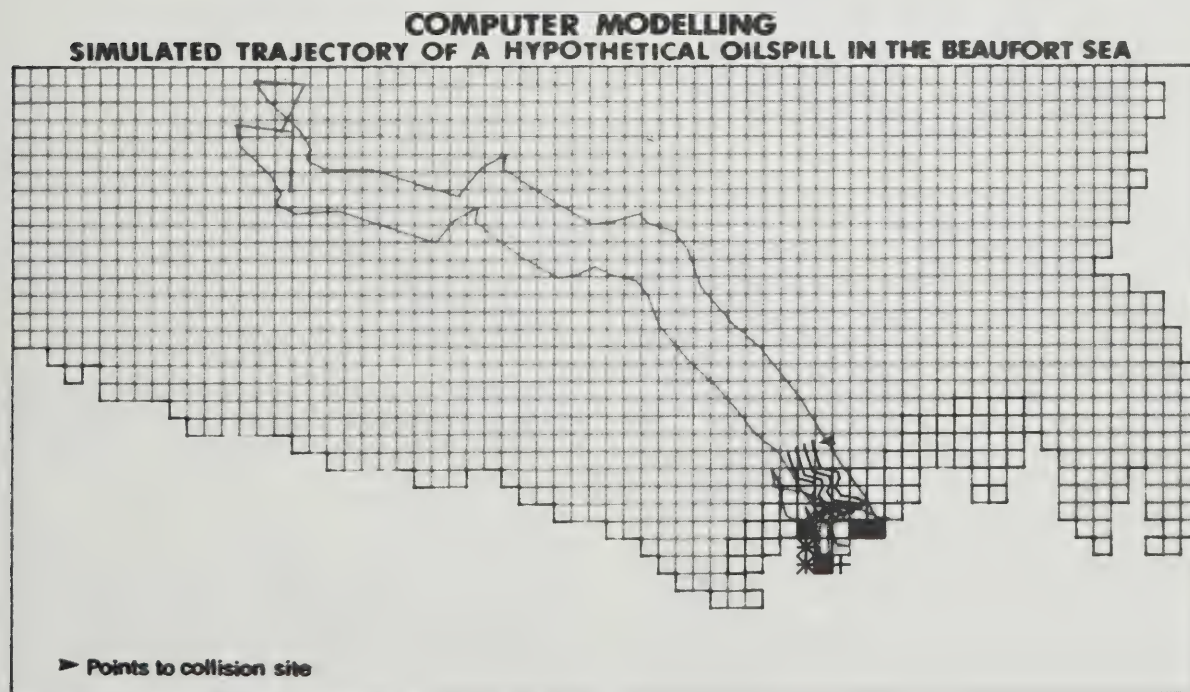
Although the risk of spills from Arctic tankers can be reduced significantly it cannot be entirely eliminated. To this end Dome has commenced work to address the clean-up of tanker spills in the Arctic. All of the techniques presently available for spill response in support of exploration activities in the Beaufort Sea would be used to respond to tanker spills.

In order to illustrate the response to a tanker spill, a hypothetical accident scenario is presented for the Beaufort Sea during open water conditions.

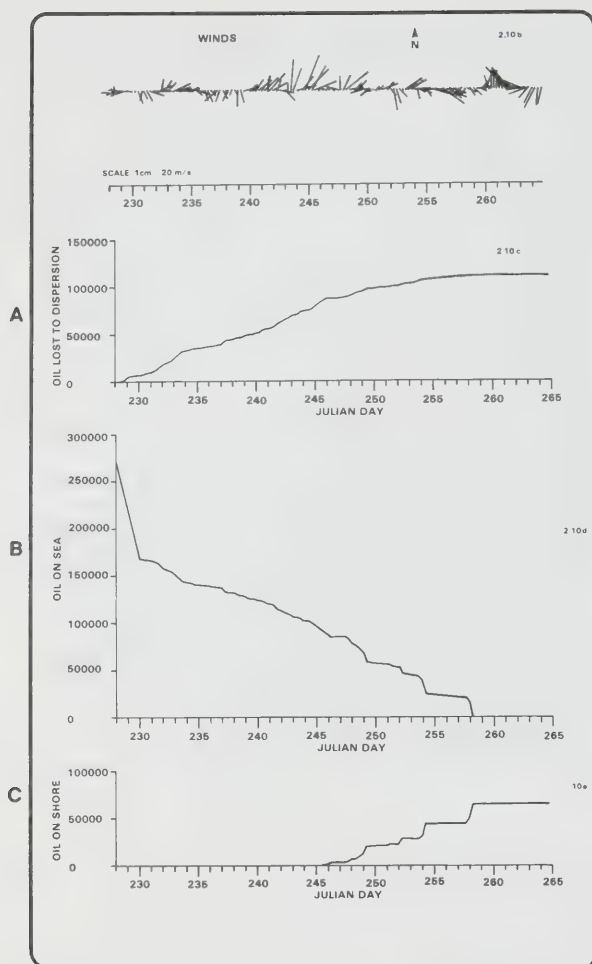
##### (i) Tanker Collision in the Beaufort Sea Scenario

In this hypothetical incident it is assumed that an Arctic tanker is involved in a collision of such tremendous force with another tanker that it tears a hole through both hulls on one side. This results in the discharge of 75% of the oil in two tanks, some 43,000 m<sup>3</sup>, into the water in a period of four hours. In order to ensure the safety of the crew and vessel the master returns the tanker to the Kopanoar loading facility.

Once the oil spills, it begins to spread on the water and to break down through ageing and other processes. A computer model of the trajectory of the slick, moved by winds and currents, is shown in Figure 4.3.2. Figures 4.3.3a, b and c illustrate the amount of oil predicted to be entrained in the water column by natural dispersion, the amount of oil on the sea surface as slicks and the amount that may impact the shorelines. It should be emphasized that the computer model does not take into account any efforts to contain and clean up the spill. The trajectory thus represents the "do nothing" scenario.



**FIGURE 4.3.2:** Computer modelled oil spill trajectory of a hypothetical oil slick from a tanker spill in the Beaufort Sea during the open water season.



**FIGURE 4.3.3:** Provides information on oil resulting from a hypothetical spill in the offshore Beaufort over time.  
 A — Identifies the amount of oil lost through dispersion.  
 B — Estimates the amount of oil on the sea surface.  
 C — Estimates the amount of oil reaching shore.

## (ii) Countermeasures Strategy

Immediate steps would be taken to control the source of the oil. First, oil from the damaged tanks would be pumped to undamaged ballast tanks. The second step would be to deploy radio spill tracker buoys so that the slicks could be found even under conditions of poor visibility. At the same time, containment booms and skimmers stockpiled at shore bases, on ships and on islands in the area would be dispatched to contain and recover the oil. The Dome Response Barge would be used offshore as a recovery, processing and disposal site.

Aircraft, with both human observers and remote sensing equipment on board, would be used to monitor the movement of any slicks escaping the containment and recovery operations. Information on the position of slicks combined with weather forecasts would be used to predict the movement of the oil and any possible shoreline impacts. The Beaufort Sea Shoreline Protection and Cleanup Manual

would be used to identify and prioritize any shoreline areas threatened by oil. Shoreline protection equipment (booms, skimmers, etc.) would be dispatched to protect the most sensitive areas based on advice from specialists. If equipment beyond the resources available in Tuktoyaktuk were required they could be obtained from Government and industry inventories across Canada and the U.S.

If prior Government approval were received, chemical dispersants could be sprayed on slicks approaching shorelines. These chemicals accelerate the natural process of dispersing oil slicks into the water column thus minimizing the threat to birds and marine mammals. Supply boats with the capability to spray dispersants are available in the Beaufort Sea and special Canadian spray aircraft can be chartered quickly.

Any shorelines that were polluted with oil would be cleaned using the proven techniques prescribed in the Shoreline Manual. The oil recovered by both shoreline and nearshore clean up operations would be safely disposed of using helicopter-portable burners, incinerators and kilns and, if necessary, by burial in approved sites.

In summary all available offshore countermeasure techniques (containment, recovery, dispersants, etc.) would be used to prevent the oil from reaching sensitive shoreline; however, should the slick threaten the shoreline then the major emphasis would be on nearshore and shoreline clean-up. Despite the size of the operation an effective response could be carried out. It should be noted that if the accident were to occur during winter or spring, there would be a much greater opportunity to contain, burn and clean up the spill while it was at sea, and far less chance of it reaching the shore, due largely to the presence of shorefast ice, which provides a natural barrier to oil movement.

## (g) On-Going Oil Spill R&D for Tankers

The following summarizes the objective of several important R&D projects presently being proposed in relation to Dome's plans to transport oil by tankers through the Arctic.

### (i) Baffin Island Shoreline Videotapes

To complete the catalogue of annotated shoreline cleanup videotapes for the proposed tanker corridor the coastlines of Lancaster Sound and Baffin Island will be recorded.

### (ii) Northwest Passage Shoreline Protection and Cleanup Manual

To be prepared to respond effectively to an oil spill threatening coastlines of the Northwest Passage a manual, similar to the Beaufort Sea manual, is being produced.

#### (iii) Burning in Tankers

In some accidents, as a last resort, the deliberate burning of a tanker and its cargo can prevent extensive pollution. This project will attempt to develop criteria to logically assess when and how such an action might be undertaken.

#### (iv) Spill Response Equipment for Tankers

This project will assess the feasibility and applicability of placing a stockpile of response equipment including booms, skimmers, workboats, igniters and tracking buoys on a tanker. The storage of these items on a tanker will be addressed, as will the establishment of shorebased equipment stockpiles.

#### (v) Use of Dispersants

A computer model will be used to determine in which areas, if any, chemical dispersants could be used on oil slicks to reduce their environmental impact to key species, particularly birds and marine mammals. The purpose of this program will be to provide cleanup teams and regulatory agencies with a decision-making tool. The study will focus primarily on the Beaufort Sea. If it proves successful it could be extended to cover the Northwest Passage.

#### (vi) Contingency Plans for Tankers

All of the existing knowledge on Arctic spill cleanup and the results of the above research programs will be combined into a contingency plan for tankers. This plan, to be developed in close co-operation with government agencies, will ensure that an effective coordinated response can be made to tanker spills should they occur. Continuing training, exercises and research will be used to update the plan regularly.

#### (h) Conclusion

The foregoing has shown that although tanker accidents have taken place in the past, they can be avoided by proper design, equipment and operation. The Arctic tanker will be at least 120 to 160 times safer than a conventional oil company tanker operating on a southern Canadian route.

Specific features have also been designed into the tanker so that in the event of a grounding the chances of oil being spilled will be minimized.

Notwithstanding all these safety features, there remains the remote possibility that a tanker spill might occur. Effective responses to spills in the Beaufort Sea and the Northwest Passage can be made with the existing and constantly improving oil spill cleanup systems. By researching and developing new techniques the response capability will be enhanced. Before tanker transport of oil through the Northwest Passage commences, appropriate contingency plans and equipment will be in place.

## 4.4 ENVIRONMENTAL RESEARCH

Since the beginning of exploratory drilling activities in the Mackenzie Delta and Beaufort Sea, there have been concerns about possible negative impacts of the industry's activities on the region's biological resources including whales, seals, polar bears, birds and fish. To address these concerns and the underlying biological principles which operate in the area, government and industry, with increasing involvement of the northern people, have been carrying out relevant biological and chemical research programs.

Table 4.4.1 provides an outline of the major areas of biological/chemical research in which Dome has been involved in recent years. The table is divided into two categories of programs, those of a broad biological baseline gathering nature, and those intended to assess specific types of impacts/concerns. The research and monitoring programs are continuing. Studies will be modified and new programs added as and when new concerns are identified.

**TABLE 4.4.1**  
**GENERAL BIOLOGICAL PROGRAMS SUPPORTED BY**  
**DOMESTIC PETROLEUM IN THE BEAUFORT SEA REGION**  
**1979-1982**

<b>A. BASELINE BIOLOGICAL PROGRAMS</b>
• SEAL DISTRIBUTIONS AND POPULATION NUMBERS
• SEABIRD DISTRIBUTIONS AND POPULATION NUMBERS
• BOWHEAD WHALE DISTRIBUTIONS AND POPULATION NUMBERS
• BEAUFORT SEA PLANKTON AND WATER QUALITY SURVEYS
• COASTAL ZONE CHARACTERIZATION OF THE REGION
<b>B. IMPACT ASSESSMENT PROGRAMS</b>
• DRILL MUDS AND THEIR IMPACTS UPON THE BIOTA
• DREDGING IMPACTS UPON BOTTOM LIFE AND FISH
• ICEBREAKING IMPACTS UPON SEAL DISTRIBUTIONS
• SHIPPING AND OFFSHORE ACTIVITY IMPACTS UPON WHITE WHALES AND BOWHEAD WHALES
• UNDERWATER NOISE IMPACTS UPON MARINE MAMMALS
• ARTIFICIAL ISLAND IMPACTS UPON POLAR BEAR DISTRIBUTIONS

**TABLE 4.4.1:** *General biological programs supported by Domestic Petroleum in the Beaufort Sea region 1979-1982.*

To date the results obtained have been very encouraging. To our knowledge no significant impacts of the oil industry's offshore operations have been recorded. In certain cases, as with white whale migrations near the Mackenzie Estuary, early detection of potential problems has allowed the industry to institute prompt mitigative measures. This in turn has assured that the normal behaviour of the white whale population has been maintained.

Beyond the basic and important field programs, Dome, in cooperation with Esso and Gulf are preparing a major Environmental Impact Statement pertaining to future Beaufort development. These documents, scheduled for completion in the spring of 1982, will be submitted to the Environmental Assessment and Review Panel (EARP) on Beaufort Sea Development. The results of the review will form the basis for projecting future environmental, social and other impacts which may or will be associated with the development of the regions' hydrocarbon resources over the next 20 years.



**PLATE 4.4.1:** *Polar bears, a valuable species to the Inuit, frequent the offshore drilling area during winter and have been known to come onto offshore drilling islands.*

The environmental impact statement also examines the issues associated with each of the two principal options under consideration for transporting hydrocarbons to southern markets. The proponents of Beaufort Sea development believe that both options are viable and that indeed eventually both may be employed. However, since Dome has a particular interest in the shipment of oil by tankers, and other operators have discussed pipeline related issues in detail, we will take this opportunity to examine some of the major concerns related to the marine transportation option.

#### (a) Oil Spills

Notwithstanding the safety and spill prevention design characteristics of Arctic tankers, the greatest fear over the marine transportation of oil cargoes centres around the possibility of an oil spill. In order to gain a better understanding of the impacts associated with major oil spills in the marine environment, Dome commissioned a study to examine the scientifically documented literature on these impacts for approximately 100 significant oil spills which have occurred worldwide over the past two decades. Encouragingly, the results of this study demonstrate clearly that the impacts from the vast majority of these accidents were transitory and local and did not cause the degree of long-lasting negative impacts often predicted. This report will be made available upon request.

It is recognized that the Arctic environment has not been subjected to any major spills, but referring to the history of

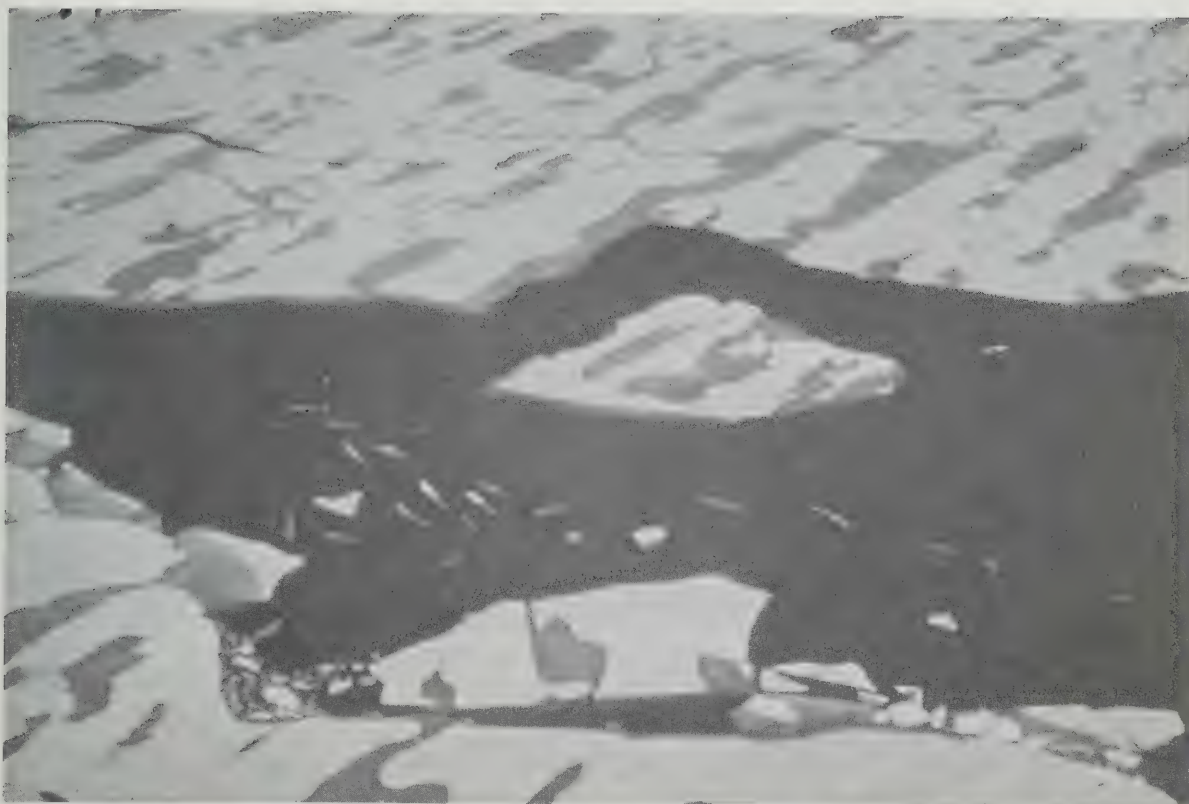
previous spills in other places, it is important to note that no oil spill has to anyone's knowledge significantly affected for example, a fishery in the long term. The Ixtoc oilwell spill, the Amoco Cadiz tanker spill and the Arrow and Kurdistan tanker spills provide recent, relevant examples.

##### (i) The Ixtoc Oilwell Spill — Gulf of Mexico (warm water)

In this well blowout situation, some of the oil was burned up at the well site and the remainder dispersed into the sea. Of the millions of barrels of oil spilled, 3,900 tons of oil are known to have reached the shores of southern Texas. Surprisingly, the birds in the area appeared to adjust their distribution to avoid oil patches and few birds were severely oiled. No significant effects attributable to the oil were noted for bottom-dwelling organisms.

##### (ii) The Amoco Cadiz Oil Tanker Spill — Brittany (temperate water)

In contrast to the Ixtoc spill, while the overall impact to birds was also not extensive, there was a significant initial impact on the plants and animals of the intertidal zone and to the fishery including the oyster fishery. Only one component of the fishery (oysters) has still not fully recovered but this is largely because the fishery is not indigenous to the area and oyster larvae (spat) are brought in from the south to grow for four years before being harvested. The intertidal zone is recovering and there appear to be no discernable impacts to the rest of the fishery.



**PLATE 4.4.2:** Up to 7,000 beluga whales have been counted in the shallow waters of the Mackenzie River estuary during the summer season. Industry carries out aerial monitoring programs every year to determine where the whales are, and to redirect ship traffic if necessary to ensure that possible interference to the whales is minimized.

(iii) The Arrow and Kurdistan Oil Tanker Spills —  
East Coast (subarctic waters)

Chedabucto Bay, Nova Scotia was the site of the Arrow spill. Almost a decade later, oil from the tanker Kurdistan also found its way to the shores of the bay. The Arrow spill resulted in initial mortality to some littoral plants and animals but the system recovered, though some oil still remains buried in the sediment. Although fishing gear was oiled, the fishery, especially the lobster fishery, did not appear to be affected by the Arrow incident. Similarly, the oil from the Kurdistan was responsible for some bird mortalities but apparently had no effect on the lobster or other fishery except for some oiled fishing nets.

Much of the research on the fate, effects and countermeasure strategies related to oil spills has been reviewed in the Oil Spill Research section of this document. Work is also being undertaken through the joint industry/government Baffin Island Oil Spill Project. The environmental effects of beached oil and of oil and oil dispersant mixtures is being investigated in a series of small experimental bays in the Cape Hatt area of the north coast of Baffin Island. The project is not yet complete.

As part of our upcoming submission to the EARP panel Beaufort Sea hearings, a series of hypothetical oil spill environmental impact predictions have been prepared.



**PLATE 4.4.3:** Bowhead whales are an endangered species which inhabits the offshore drilling area during the summer. Extensive aerial studies have been carried out since 1980 to learn more about this particularly important species and how it responds to offshore activities.

An oil spill in the Arctic will not contaminate the whole of the Arctic nor is it likely to contaminate more than a small portion of the channels or bays of the Northwest Passage. Potential hazards to birds and mammals are confined in time and space with many of them being absent during much of the year when the route is ice-covered. Relatively few animals would be exposed to potential impacts during the ice-covered season should a spill occur then.

In summary, the record of past oil spills has been that they have generally resulted in short term physical impacts and disruptions of the ecosystem. Longer term significant effects, beyond two to five years have been limited or largely absent. While prevention of oil spills will continue to be a key in the oil transportation strategy, it should be recognized that the oil spills which have occurred to date have not resulted in the types of environmental catastrophies usually predicted. Similar results would be expected in the Arctic, in the unlikely event of a major spill.

#### (b) Icebreaking and Icebreaker Tracks

A second important concern to northern hunters and trappers relates to the tracks made by icebreaking ships through ice. Specifically, there is concern that icebreaker

tracks will keep hunters and trappers from their usual hunting grounds. The concern is that vessel tracks will leave people cut-off from home or hunting grounds or be set adrift on an ice floe cut loose by an icebreaker. There is also concern that icebreaking could directly affect seals and whales.

Dome, in cooperation with other companies, is addressing this concern through several undertakings. To better understand the overall implications, studies are or have been undertaken in the eastern and western Arctic to determine the location of hunting areas, the routes to and from those areas and the frequency and timing of hunting trips. This information will define the parts of the route where, and times of the year when extra-special care will need to be taken to avoid possible conflicts with hunting and trapping activities. This work is being undertaken in cooperation with various hunters and trappers associations, BRIA and the ITC.

In addition, the nature of the track left by an icebreaker, and the ability to cross it by skidoo and komatik is being investigated during ice formation (November 1), maximum ice thickness (March-April) and ice break-up (June) within the time frame the hunters and trappers are usually



**PLATE 4.4.4.:** The only subsea oil well blowout reported to-date — 1979 Mexican IXTOC 1 blowout — is shown in the above aerial photograph. Although studies are continuing, the environmental implications of the spill appear to have been minimal.



**PLATE 4.4.5:** *The icebreaker Kigoriak, followed by three Supplier vessels, sails out of the Arctic twilight during the experimental icebreaker track research program conducted in November and December of 1981 in the Beaufort Sea.*

on the ice. Two research teams have been formed, ice research and track-crossing. The ice research team comprises ice research scientists with northern technical support. Their task is to describe ice conditions and to measure parameters related to refreezing rates, ice thickening, etc. to better understand these processes.

The track crossing team is composed of northern hunters and trappers from Tuktoyaktuk, Sachs Harbour, Holman Island and Paulatuk. Their job is to establish the criteria for crossing icebreaker tracks, to determine the times and conditions under which the tracks will be safe to cross in various modes, to develop procedures for crossing the tracks and to recommend solutions to problems should they be encountered.

The first phase of the experiment took place on November 29, 1981. The icebreaker Kigoriak followed by three ice-breaking supply vessels were travelling through the frozen channel into McKinley Bay. The ice was about 30 centimetres thick. The ice quickly consolidated behind the track. After one hour, the research team was able to walk across the track; after two and one-half hours, the hunters and trappers took a skidoo across; then they crossed with skidoo and laden (560 kg/1250 lbs) komatik.

The icebreaker track research program is continuing; should problems be uncovered, the next step will be for the team to develop satisfactory solutions.

In another research program, the Kigoriak icebreaker was used to assess the response of seals to icebreaking activity in the spring. The initial results of the study conducted in 1980 were very encouraging; there was no apparent change in the distribution of seals during the test period. The plan

is to continue this kind of monitoring as the level of ice-breaking activity in the Beaufort increases.

#### (c) Underwater Sound

A concern has been raised that the introduction of year-round shipping using large icebreaking vessels in Arctic waters could raise underwater sound levels to an extent that marine mammals may be adversely affected. Many marine mammals rely on self-generated sounds for communication and orientation. Since the marine mammals are an important traditional food source for the Inuit in Canada and Greenland, any detrimental impacts upon these natural resources could have significant implications for the people of the region.

Recognizing the importance of this concern to the Inuit, Dome and the other Arctic operators are undertaking or becoming involved in various programs to evaluate the possible impacts of underwater sound from ships. As part of the APP project, Dome ship design staff are participating in various tests to maximize the efficiency of propellers to be used on future ships. The more efficient the propeller, the quieter it will be. These tests will be used to design the most efficient and therefore quietest propellers possible. In fact, preliminary results do indeed suggest that these ships may well be quieter than many of the larger ships currently plying Arctic and southern waters.

In addition to the industry sponsored studies, the U.S. Bureau of Land Management has been carrying out studies in the Canadian Beaufort Sea on the endangered bowhead whale, looking specifically at the reactions of these whales to underwater sounds produced by oil and gas activities. Results to date have been encouraging and support the



**PLATE 4.4.6:** Experienced hunters of the northern region and research scientists are combining their skills during the ice track crossing program, which will help to determine how quickly a ship's track can be safely crossed after passage of a ship.

view that these whales do not appear to be particularly disturbed by underwater sounds originating from industry activities.

We continue to be optimistic that ongoing and future studies will further confirm the hypothesis that although the concern about underwater noise is genuine, it will not result in a significant problem.

#### (d) Conclusion

Environmental concerns have been discussed between Beaufort Sea communities and the oil industry for several years now and all companies have reacted positively to each of the concerns brought forward. Dome is now extending this approach to the communities and organizations of the Eastern Arctic. As a result of the communications established and the effective examination of each concern, we believe that all important information gaps are being addressed. Furthermore, we feel strongly that the

hydrocarbon developments being proposed can be undertaken within a framework of sound environmental design and no insurmountable environmental problems are anticipated.



**PLATE 4.4.7:** *This photo illustrates the rugged Devon Island coastline along the eastern entrance to Lancaster Sound and the Northwest Passage. Lancaster Sound in particular is well known for its large colonies of various seabirds and marine mammals.*



## **SUMMARY OF SECTION 5.0**

### **ARCTIC MARINE TRANSPORTATION**

5.1 Oil is the most common and largest cargo shipped by sea in the world; subject to receiving approvals, Dome proposes to transport Beaufort oil to market with powerful 200,000 tonne, double-hulled icebreaking oil tankers.

5.2 Extensive ice research programs have established ice conditions in the Northwest Passage, and ice-related design criteria for Arctic tankers are well in hand.

5.3 Through research and progressive technological development, Dome has determined the required design characteristics for future Arctic tankers.

5.4 The Arctic tanker will combine the best features of both icebreakers and tankers; the final product will be the strongest, safest tankers that may ever be built. They will be operated by highly skilled, motivated, and responsive personnel.

5.5 The Federal Government is establishing a Control Authority to regulate shipping in the Arctic. This authority, combined with the sophisticated vessels of the future and the equally sophisticated navigation aids, should ensure the safest possible transit of ships through the Northwest Passage.



5.0 ARCTIC MARINE  
TRANSPORTATION

5.1 BACKGROUND

Oil is the largest cargo shipped by sea. Measured in tonnes, 1.1 times more oil is shipped by sea than all other cargoes and 1.8 times more oil is shipped than bulk cargoes which are the second largest cargo type. Figure 5.1.1 shows the principal world oil tanker routes.

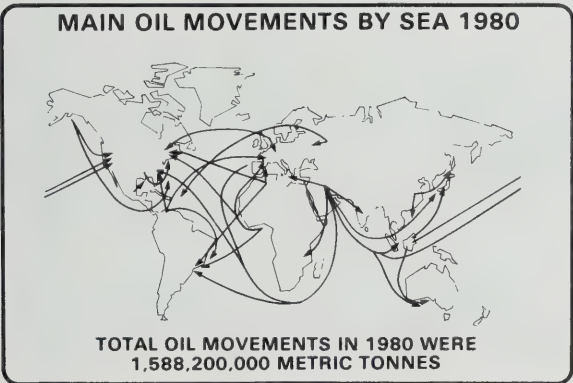


FIGURE 5.1.1: Principal world tanker routes.

The world's oil tanker fleet consists of some 3,000 vessels with a cargo carrying capacity of 320,000,000 tons. Vessels range in size from several hundred to 500,000 tonnes.

Dome Petroleum is proposing to open up a new tanker route (Figure 5.1.2) to link Beaufort Sea production sites to ports on the eastern seaboard. In time, approximately one per cent of the world's current oil cargo could be transported by tankers through this route. Current planning is to use mid-sized (200,000 dwt), specially designed tankers for this purpose. Plate 5.1.1 shows a traditional open water tanker of this size.

There has been some experience both in Canada and internationally in designing, building and operating cargo ships in ice. In Canada, ships such as the "Irving Eskimo" have been designed to operate in the pre-broken channel of the Gulf of St. Lawrence. The "Irving Eskimo" is a modified open water tanker with extra steel added in the bow for strength. Ships of this type are neither meant to break ice nor to be safe in circumstances where they could hit multi-year ice at high speeds.

In the Baltic, the Finns have designed, built and operate the Lunni class of icebreaking products tankers in an environment similar to that of the Great Lakes in winter; an environment more rigorous than that suited for the "Irving Eskimo," but considerably less challenging than the Arctic.

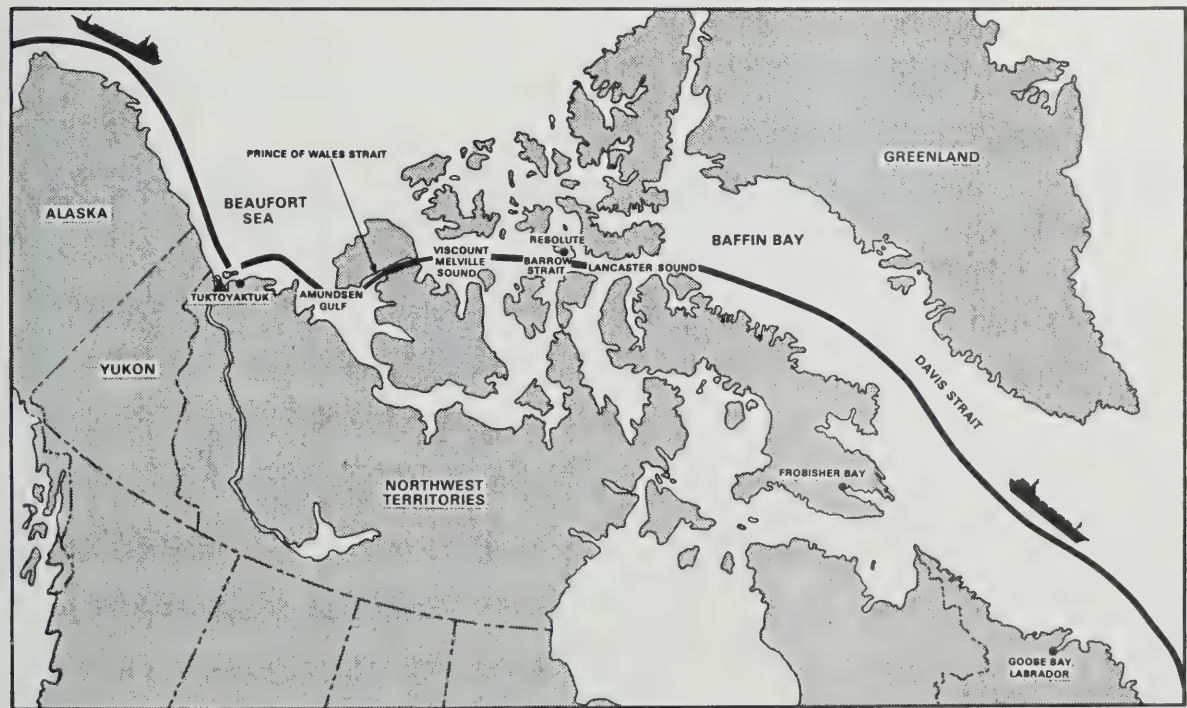


FIGURE 5.1.2: The marine route for carrying oil by tankers would proceed through the Northwest Passage to the Eastern Seaboard. An alternate, but less likely route, would head west through the Bering Strait.



**PLATE 5.1.1:** *A conventional open water tanker comparable in size to the proposed Arctic Tanker.*



**PLATE 5.1.2:** *The ice-strengthened "Irving Eskimo" has been designed to operate in conjunction with icebreakers during the winter in southern Canadian waters. Arctic tankers will be designed to operate independently of icebreakers.*

The Lunni class is also a modification of the traditional open water tanker; however, it includes many characteristics specifically suited to icebreaking. These include:

- icebreaking hull form,
- circular stem,
- sloping sides
- ice-strengthened hull,
- hull coated with Inerta 160 (a friction reducer),
- ice-strengthened propeller,
- double shell and double bottom, and
- air bubbling system.

The Lunni class will break up to one metre of ice and their double shell and bottom are designed to prevent leakage of cargo and increase safety should the hull be pierced. Again, the Lunni class was not designed to withstand collisions at high speeds with multi-year ice.

The modifications seen in these Canadian and Baltic ships have been relatively minor and to a large extent, their design and governing regulations have been simple extrapolations from the open water experience. Conditions and ice regimes in the Arctic are much more rigorous and even unique compared to those encountered elsewhere. In recognition of this, Dome has undertaken 10 years of basic ice research throughout the Beaufort Sea and Northwest Passage region.

5.2 ICE CONDITIONS

The characteristics of ice can initially be split into two main areas; the micro level which concerns the strength of the ice under various conditions and the macro level which concerns the way the ice forms large structures.

Looking at ice as an engineering material on the micro level, it has properties very different from steel but quite similar to concrete. Table 5.2.1 compares ice, steel and concrete strengths. From this, ice is seen to be strong in compression but weak in tension and shear. It is in these modes that an icebreaker should seek to break the ice.

Secondly, the strength of ice depends upon temperature. As the temperature falls so the strength of the ice increases, as shown in Figure 5.2.1. It is not practical to try to raise the temperature of ice and so an icebreaker must be designed to operate for the high strength of ice which occurs during the coldest part of any given operating season.

Finally, the strength of sea ice depends upon its age or more correctly, its chemical composition, which changes as the ice ages. When first year sea ice forms, pockets of salt are trapped within it. These weaken the ice. During the next summer however, as the ice warms, the salt will begin to leach out of it and the spaces become filled with fresh water. If the ice survives the summer, it becomes second year ice which is much stronger. Thus it is the older multi-year ice, particularly the polar pack, which produces high forces on an icebreaker.

On the macro level there are four major ice types:

(a) Level Ice

If there are no winds or currents then ice will form in a level sheet. This level ice is the sort which can be seen on lakes. The thickness of this ice grows as the winter progresses. Level ice forms the greatest proportion of the first year ice and is the easiest of the macro structures for an icebreaker to break.

(b) Pressure Ridges

Winds and currents cause the ice to move. If this movement is restricted by the land or jammed ice, then the level ice will begin to break and pile up, forming pressure ridges.

A typical resulting ridge can have a sail of 5 metres and a keel of 20 m. Ridges are an amalgam of ice blocks which are not solidly welded together. The thickness of consolidated ice is normally less than twice that of the surrounding level ice. If the pressure ridge moves into shallow water, the bottom of the keel may ground, and in the process become wider and thicker through crushing. For an icebreaker, breaking an ungrounded ridge means breaking the consolidated ice with the vessel, then displacing the unconsolidated random blocks. When the ridge is grounded the random blocks cannot disperse easily and the icebreaker has to push them out of the way.

STRENGTH	ICE	'A' STEEL	'EH36' STEEL	CONCRETE
TENSION	2-4	230	350	2-3
COMPRESSION	10-25	230	350	15-30
SHEAR	1-2	160	240	2-3

\*THE STRENGTH DETERMINED FROM SMALL LABORATORY SAMPLE.

TABLE 5.2.1: A comparison of ice strength versus steel and concrete.

### (c) Pack and Rubble

The third major ice type is pack and rubble ice. Since the wind changes directions, broken ice may accumulate but not form into pressure ridges. Secondly, the refreezing of broken ice after the summer results in pack and rubble. Lastly, rubble ice results after the passage of a ship. The most important characteristic of this ice type is that it is generally thicker and stronger than the original level ice from which it was formed. Because of its broken up nature, more ice reaches a ship's propeller when it is operating in rubble ice.

### (d) Ice Islands and Icebergs

Ice islands and icebergs are the final major ice type. Ice islands are formed when large pieces of ice shelf detach from the foot of a glacier or from landfast ice. In both cases, the shelves are composed of compacted snow which compresses into very strong fresh water ice. A typical ice island could be 4 km x 1.5 km x 30 metres thick. Small ice islands or decaying ice islands are icebergs and small icebergs are bergy bits or growlers. Since the composition of an ice island is mostly fresh water ice, they are the strongest ice feature and represent the most rigorous conditions to be addressed in ship design.

Through the Northwest Passage, depending on location and time of the year, any one or all four of these types of ice could be encountered by marine traffic.

Through extensive field and laboratory research, Dome has determined the characteristics a vessel should have in order to safely navigate year-round in Arctic waters. The basic attributes such a ship must have are summarized in Table 5.3.1.

To meet the required characteristics, design features were developed, many of which can be seen in the "KIGORIAK."

Making good speed in level ice depends on three major items. The shape of the bow must efficiently break ice, the power and hence thrust of the propulsion system must be sufficient and the friction between the hull and ice must be minimized.

The spoon shaped bow of the KIGORIAK ensures that the ice is broken in shear and in tension which are the weakest failure modes. The nozzle around the propeller gives the highest low speed thrust for a given power and the KIGORIAK has higher power proportionally than do other icebreakers. The reamer breaks a channel wider than the width of the vessel and so reduces the friction of ice along the vessel's sides. The water wash system lubricates the ice before the hull comes into contact with it.

Progressing through ridges without resorting to ramming depends on the weight and speed of the vessel. Great weight and high speed give the vessel high kinetic energy and it is this energy which breaks the ridge on impact. A small icebreaker, such as the KIGORIAK will necessarily have restricted ridge performance.

Surviving collisions with ice islands depends purely on the structural arrangement and strength of the vessel. The bow structure of the KIGORIAK was made proportionately much stronger than similar icebreakers of its class in order to allow testing to check the predicted forces.

## 5.3 THE REQUIRED CHARACTERISTICS OF ARCTIC VESSELS

**TABLE 5.3.1**  
**BASIC CRITERIA CONSIDERED IN THE DESIGN OF THE ARCTIC TANKER**

- THE VESSEL SHOULD MAKE GOOD SPEED IN LEVEL ICE.
- THE VESSEL SHOULD MAKE CONTINUOUS PROGRESS THROUGH RIDGES.
- ICE ISLANDS SHOULD BE DETECTED IN ADVANCE AND THE VESSEL HAVE THE MANOEUVREABILITY TO AVOID THEM.
- THE VESSEL SHOULD WITHSTAND A COLLISION WITH AN ICE ISLAND.
- THE PROPULSION SYSTEM SHOULD WITHSTAND BLOCKS OF ICE BEING SUCKED INTO THE PROPELLOR.
- THE VESSEL'S STRENGTH SHOULD WITHSTAND ALL THE ABOVE AND ALSO STRESSES IF THE VESSEL BECOMES BESET.
- LIFE SAVING EQUIPMENT SHOULD BE PROVIDED FOR THE CREW IN ALL OPERATING ENVIRONMENTS.



**PLATE 5.3.1:** *Dome Petroleum's prototype icebreaker, the Kigoriak, has provided marine designers with invaluable experience for the Arctic tanker. Many of its features, such as a spoon shaped bow and reamer, water spray system, and power train have been tested in the demanding environment of the Arctic for the first time.*

The ability of the propulsion system to avoid damage due to ice impact was achieved by using a controllable pitch propellor in an ice strengthened nozzle. The nozzle limits the size of ice pieces which can impact the blade. The controllable pitch mechanism ensures that the propellor speed is always kept high in order that any ice pieces which do enter the nozzle are easily milled. In addition, by keeping the speed high; torques on other items of the propulsion system such as gear boxes and shafting are kept low. The ability of the vessel to withstand the ice forces imposed upon it was achieved by using a structural arrangement which made use of standard Canadian shipyard practice but was unusual in configuration. The KIGORIAK was designed and built in 11 months, an exceptionally short period for shipbuilding. Arctic Tankers will be built in a similar manner to that of their predecessor.

The likelihood of environmental pollution caused by the KIGORIAK was minimized by not carrying any oils next to the hull of the vessel. All oil tanks therefore have a double skin. This is a requirement which is in excess of all international requirements but is now a standard Dome policy which will be applied to the Arctic Tanker. In addition, the Arctic Tanker's arrangements have been designed in such a way that even if the bottom inner skin were punctured all the oil should still be contained.

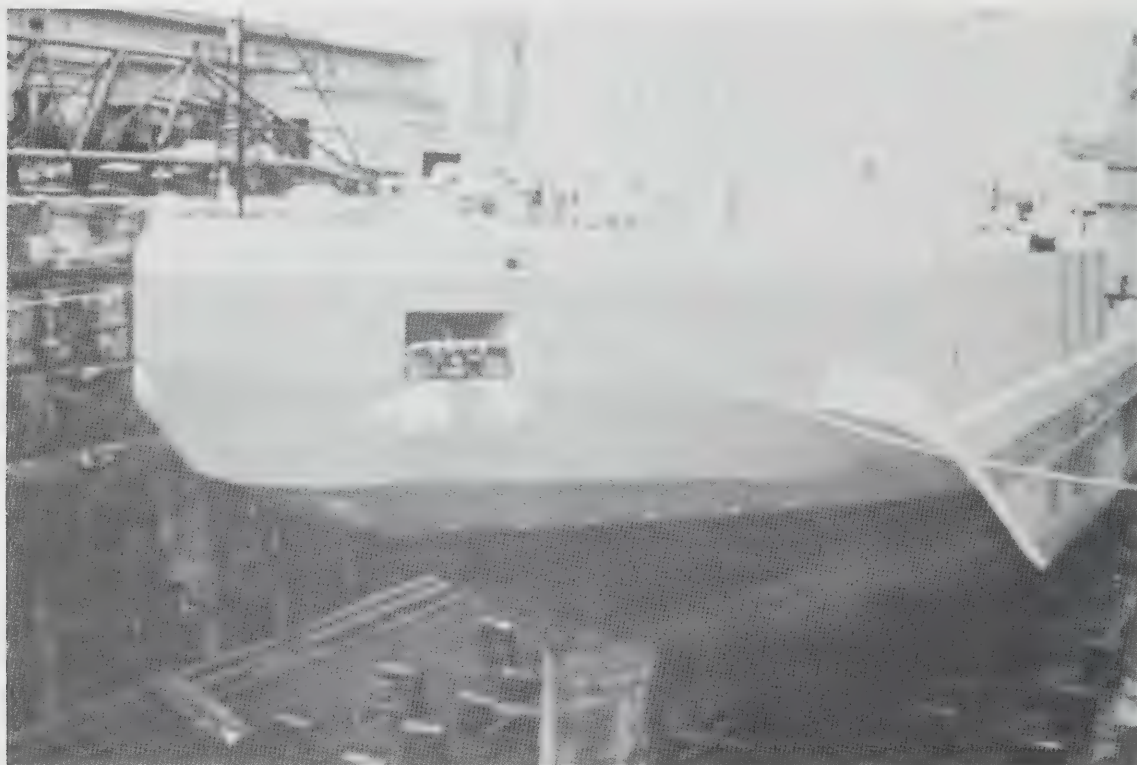
The KIGORIAK is a Canadian Arctic Class 4 ship but she is also a  $\frac{3}{4}$  scale model of the Arctic Tanker. To confirm the design methods used for the KIGORIAK would allow designers to accurately predict the performance of the Arctic Tanker. Therefore, it was important to test the KIGORIAK full scale to confirm the designs' safety factors. In a series of tests all aspects of the design philosophy were tested. The ultimate strength of the KIGORIAK was found to be Class 6/8.

Not all the proposed innovative systems of the Arctic Tanker were incorporated into the KIGORIAK and so a second test vessel was required. This vessel the "ROBERT LEMEUR" is presently under construction in Burrard Yards, Vancouver and her test program will commence before the end of 1982.

In addition to the above vessels, Dome has been operating a large fleet in the Arctic for 6 years. This experience has provided a detailed knowledge of the systems required to operate in the Arctic environment.



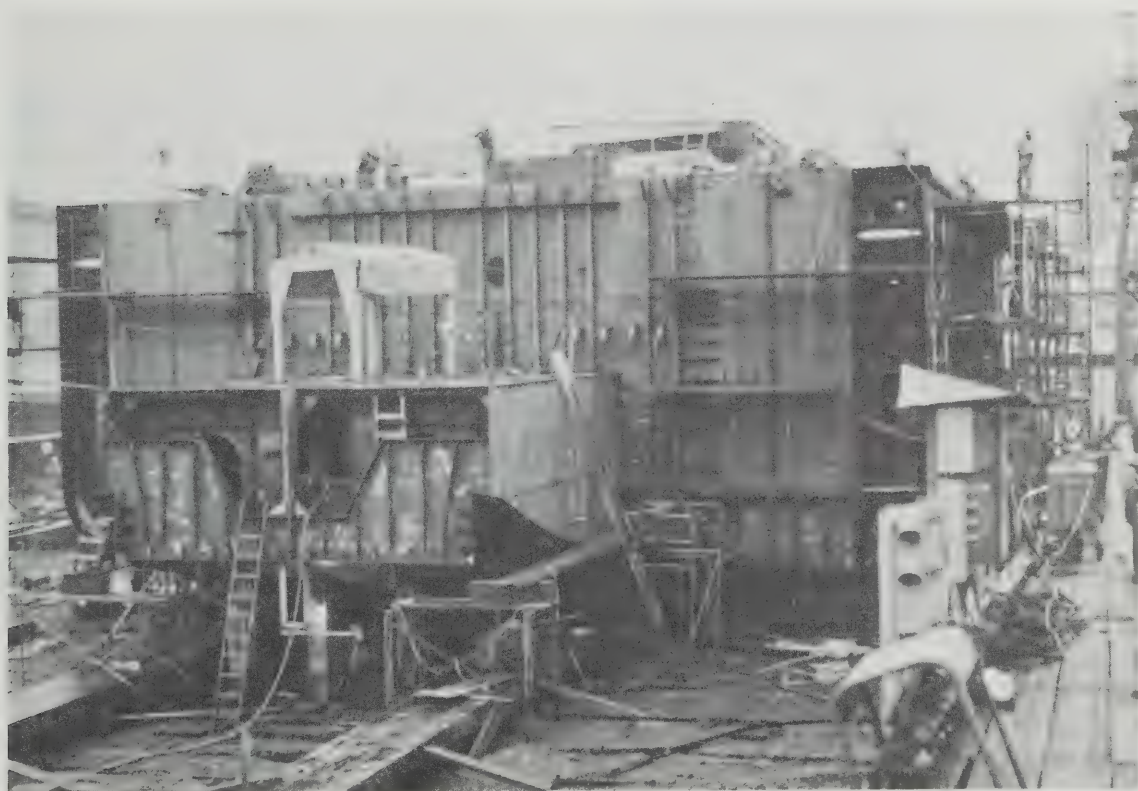
**PLATE 5.3.2:** *Kigoriak's deep-mounted propeller is well protected from ice by the surrounding protective nozzle which also serves to concentrate the forces generated by the propellor.*



**PLATE 5.3.3:** *To increase turning ability and to lessen the friction along her sides, Kigoriak's bow is equipped with a reamer to break a channel through ice six feet wider than the rest of the hull.*



**PLATE 5.3.4:** *To further reduce ice friction a water spray system has been installed on her bow and along the sides.*



**PLATE 5.3.5:** *The Robert LeMeur (formerly Supplier 9) is Dome's latest and most innovative icebreaker supply vessel. It is presently being built in Vancouver and will sail to the Beaufort in 1982. It incorporates many new features which are being considered for inclusion in the final design of the Arctic Tanker.*

Out of this experience one particularly revealing fact has been confirmed. The most "dangerous" time for an ice-breaking ship does not occur while operating in ice in mid winter, but rather during open water operations in summer ice. This is primarily due to the speed of the vessel. In heavy ice, the vessel cannot achieve high speeds and so cannot impose high forces on itself. High speed operation in the summer with a random scattering of ice islands and icebergs is potentially more dangerous, hence, Dome's emphasis on REMSCAN and ship manoeuvring and control. Fortunately however, this open water experience is well known and proven. This type of operation takes place routinely with existing cargo ships traversing Davis Strait and the Labrador Coast and is monitored and controlled by the Canadian Coast Guard using their ice reconnaissance and reporting system.

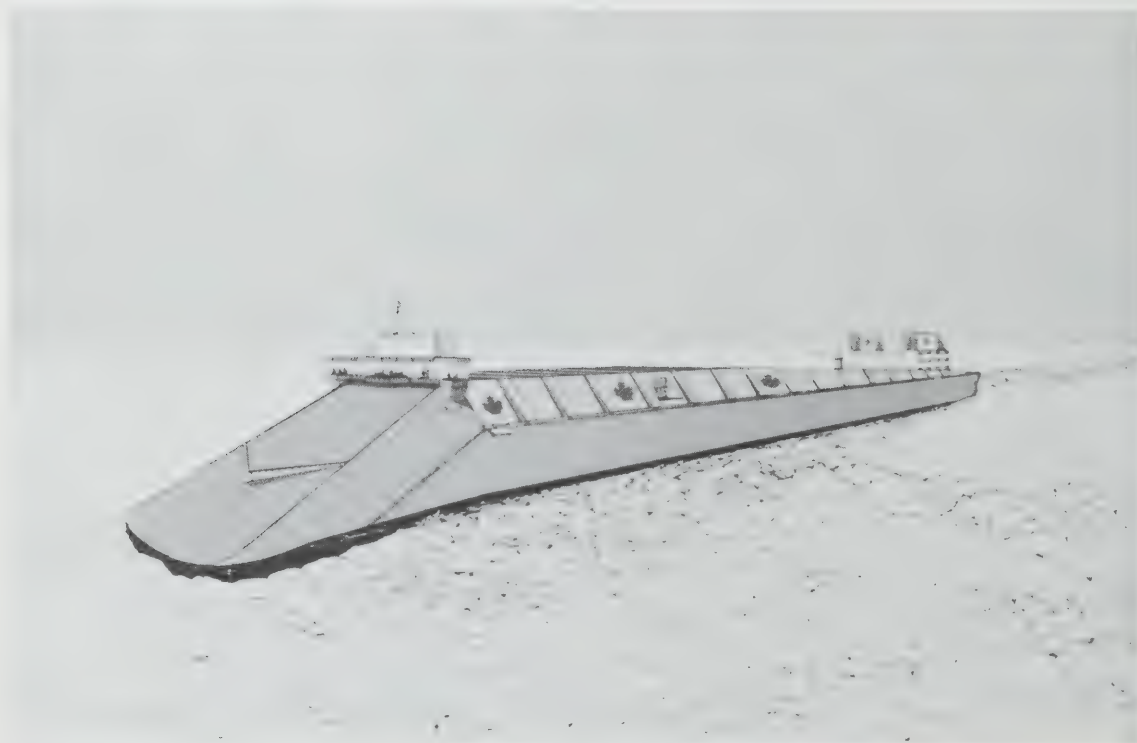
## 5.4 THE ARCTIC TANKER

The designer of an icebreaker has a much easier task than one who designs an ocean going vessel or for that matter a drilling rig. The designer of an open water vessel never has the opportunity of testing the vessel in the worst conditions. A tanker designer in Saint John, New Brunswick for example, must predict the worst environment the vessel will see in its 20 year life. One method is to use the "100 Year Wave" (there is of course a 1,000 year wave and a 10,000 year wave, etc.). The designer must then predict the performance of his ship in these conditions. The vessel may never actually see these conditions or if it does it is liable to

be on a dark stormy night in some remote part of the world and the designer will not be on the vessel. Because of this, enormous resources are committed to ship safety by the United Nations, IMCO, National Administrations, Classification Societies and the research of Universities and individual companies.

The designer of an icebreaker is more fortunate. When the ship is built it can be instrumented and in late fall the designer can go on board and the ship tested in the polar pack as the season progresses. Until March/April the vessel can be exposed to increasingly stronger and heavier ice including if necessary, ice islands. If the vessel performs satisfactorily, then the designer can be certain that the vessel has been tested in the worst conditions.

Dome's design philosophy is to design not only to existing rules, but to complement this with the basic research needed to better understand the problems. Having understood the problems a better design is then produced. At that stage, it is compared back to the Regulations to ensure that all aspects of the vessel are equal to or exceed the highest international and national regulations. What is worrying however, is that in many ice-related areas, the company's in-house requirements considerably exceed the existing Rules and Regulations, and Dome has concern that other parties may indeed run into problems if they design exactly to the rules.



**PLATE 5.4.1:** The tankers being proposed to transport oil through the Arctic seas will be ice Class 10,200,000 DWT double-hulled vessels with an oil carrying capacity of 1.5 million barrels.

While the Arctic tanker design cannot be merely a further extrapolation of the open water experience, it is basic to the design of the new generation of ships to understand this experience, particularly as related to safety. With a desire to know and examine the details of oil tanker accidents, Dome commissioned Det Norske Veritas (Ship Division) to carry out a "Tanker Oilspill Analysis Study" of all recorded tanker oil spills of more than 200 tons between January 1967 and December 1978. The objectives of the study were to identify design features and safeguards that could prevent or reduce the size of oil spills if incorporated into the Arctic tanker design and operation.

The data base for the study included D.N.V.'s own damage registers, Oil Spill Intelligence Reports, U.S. Coast Guard Polluting Incident Reports, Lloyds List and Liberian authorities. The study presented statistical summaries of tanker incidents as well as details on twenty of the best documented spills during the eleven year reporting period. From this study it can be seen that there are five major types of casualties (Figure 5.4.1).

These casualties are the end result of a particular failure of part of the overall ship system. By taking each one and working back, the failures listed in Table 5.4.1 were identified.

The cause of the accidents, or failures can be grouped into "HARD" or equipment failures and "SOFT" or man/system failures.

Whereas the study only showed certain failure combinations, almost any combination is possible, and many of the casualties were caused by a combination of one hard failure with two or more soft failures.

Soft failures have only received detailed study and research in the last fifteen years, with the result that documentation and analysis are currently less than complete. From the still limited knowledge, a group of five somewhat overlapping soft failures have been defined. Having identified the main types of failures, Dome has taken steps to prevent or minimize their chances of occurring in the future Arctic tanker. The major steps being taken are summarized as follows:

1. Improvements of the ships engineering systems have been achieved by the twin shaft arrangement which allowed 100% redundancy of all major components. The components themselves were chosen from well proven marine equipment.
2. Dramatic improvements of the hull structure over that of existing ships have been made. The Arctic Tanker will have a bow strength approximately 75 times stronger than that of a conventional open water tanker of the same size, and 5.5 times stronger than that of one of the new Canadian Coast Guard ice-breakers, the "Pierre Radisson".

The midships strength of the Arctic Tanker will be approximately three times that of an open water tanker. The mode of operation however, is more important; when an open water ship is caught in rough weather it cannot escape. The master must just heave to and wait; in a typical North Atlantic storm the waves will be rising and falling 15 metres (45 feet) every 12 to 13 seconds, thereby subjecting a vessel caught in these circumstances to major stresses. For an icebreaking ship, however, the hull will be strengthened well beyond that needed to accommodate

**TYPES OF FAILURE EXPERIENCED DURING TANKER ACCIDENTS**

**"HARD" FAILURES**

- A. FAILURE OF SHIP'S ENGINEERING SYSTEMS**
- B. FAILURE OF HULL STRUCTURE**
- C. FAILURE OF SHIP'S CARGO HANDLING SYSTEM**
- D. FAILURE OF SHORE SIDE CARGO HANDLING SYSTEM**

**"SOFT" FAILURES**

- A. MAN/MACHINE INTERFACE FAILURE**
- B. TRUE RANDOM HUMAN ERROR**
- C. FLOUTING THE LAW**
- D. INCOMPETENCE**
- E. SOFT SYSTEMS FAILURE**

**TABLE 5.4.1:** *Types of failure experienced during tanker accidents (based on Det Norske Veritas study).*

## MAJOR TYPES AND CAUSES OF TANKER ACCIDENTS

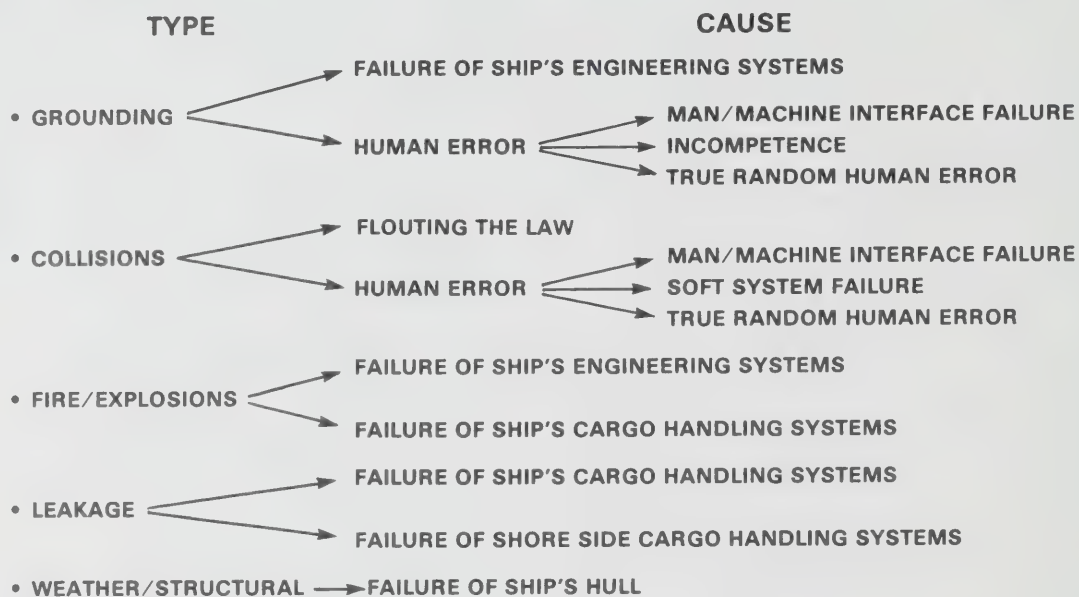


FIGURE 5.4.1: Major types and causes of tanker accidents.

waves, and therefore, major stresses are only imposed on the vessel when it enters difficult ice. This means that the vessel can be instrumented with stress alarms which will warn the master when he is approaching over-driving of the vessel, and should slow down.

3. The most advanced and best cargo handling system will be employed. The failures of ship's cargo handling systems were the subject of intense research in the late 60's and early 70's, culminating in IMCO legislation. Fire can occur when fuel, oxygen and an ignition source are found together. For many years successful loading operations took place by separating the ignition sources from the cargo. However, a number of accidents occurred which showed that this was not a foolproof approach, so the principle of inert gas was adopted. In this situation, the oxygen in the air above the cargo is replaced by inert nitrogen and carbon dioxide. This system will be employed on the Arctic tanker. Secondly it was discovered that the use of a pumproom deep in the body of the ship could give rise to the collection of explosive gases. The solution to this was to install a submerged pump in each tank and to have the operating machinery on deck. This also facilitates control, particularly in the event of leakage.
4. Instrumentation, automation and computer controlled systems incorporating the most advanced electronic, hydraulic and pneumatic equipment will be extensive,

as will the ship's auxiliary and associated cargo machinery.

5. Navigational aids and ice detection systems will incorporate the most advanced "state of the art" equipment including computer controlled collision avoidance systems, infra red detection, low light level television and high resolution radar.
6. Special attention is being given to ship's personnel and their needs, to ensure use of the highest levels of expertise, alertness, awareness, and other factors which together will serve to minimize human error.

The shipment of oil from the Beaufort Sea by Arctic tankers will be a Canadian energy transportation project. The ship's manning and officer certification requirements will be governed by the Canada Shipping Act and the Arctic Waters Pollution Prevention Act, and Dome will exert every effort to locate, recruit, train, and appoint Canadian officers and crew. The expertise required of the ship's officers and crew will, however, be exceptional by any standard.

## 5.5 TRAFFIC CONTROL

The petroleum industry, through projects such as the Arctic Pilot Project, Beaufort Sea Development and others, are

predicting an increase over time in the number of ships plying the Northwest Passage. Proper controls will be required to ensure the safest possible passage of these future ships through the region.

In response to these pressures, and in compliance with the recommendations of the EARP panel for the Arctic Pilot Project, the Federal Department of Transport is in the process of establishing a CONTROL AUTHORITY. The primary role of the Authority will be to plan for the management of shipping routes and ship movements in the Arctic, particularly the Northwest Passage, on behalf of the Government of Canada, and to provide guidance to the individual Coast Guard directors with related program responsibilities.

An important purpose of the Control Authority is to provide a forum for the receipt of environmental and related advice and concerns from a new Environmental Advisory Committee (EAC), and to integrate that advice into the planning framework for management of shipping routes and ship movements in Arctic waters. The EAC has been set up to ensure that the Control Authority receives appropriate environmental information and advice on those aspects of the environment, natural resources and transportation that may be affected by Arctic shipping routes and ship movements.

The section of the Coast Guard responsible for implementing the plans of the Control Authority will be the Northern Branch in Coast Guard headquarters, which is a developmental branch that will evolve into a Coast Guard Arctic Region, based in Resolute. The Northern Branch will assume responsibility for the plans, programs and resources required to monitor and manage shipping routes and ship movement. One of the first tasks to be assumed by the Region will be that of vessel traffic management (ship routing) in Arctic Waters.

Presently there is a monitoring system in operation called NORDREG. NORDREG was previously a voluntary system but Cabinet has recently directed that it be made mandatory. NORDREG is basically a vessel monitoring and support information system. Vessels entering Arctic waters must give 24 hours notice and must meet Coast Guard standards before being allowed to proceed. In turn vessels are provided with information on weather, ice and other vessel movements. NORDREG is presently operated from Frobisher Bay during the summer.

The institution of the Control Authority, in combination with the highly sophisticated vessels of the future and the equally sophisticated supporting navigation aids should ensure the safest possible transit of ships through this important area of the north.



## **SUMMARY OF SECTION 6.0**

### **INDUSTRIAL AND ECONOMIC BENEFITS OF NORTHERN DEVELOPMENT**

6.1 During the six years that Dome has been active in the Beaufort Sea region, one of the most important guiding principles has been to maximize opportunities for northerners and to minimize possible negative effects of the operations. The total number of northern employees hired, wages earned, local businesses supported and other indicators have all shown a tremendous growth over this short period of time.

Dome also carries out an active community liaison and consultation program and is involved in several direct and indirect training programs leading to the development of a trained northern workforce so vital for the future.

6.2 Considerable benefits have accrued to Canada as a result of the ongoing exploration program and more can be expected as operations progress to the production phase. As an example, in 1981, total Beaufort-related direct expenditures were in the order of 482.0 million dollars, while the 1982 budget is expected to approach 700 million dollars. Capital items which have been purchased or constructed in Canada over the past few years have included many of the supply boats and smaller vessels, the icebreaker Kigoriak, the caissons and drill package for Tarsiut and the Tuktoyaktuk base camp.

Beaufort Sea development appears to complement all of the Government's priority strategic policies and programs, namely Industrial Development, Reserves Development, Transportation, Export Promotion and Human Resources.

With the aid of an economic model, Dome has projected the possible impacts of various levels of Beaufort development on the Canadian economy. The implications will extend across the country and will include raising the Gross National Product, improving the Government's revenue standing — perhaps to a surplus level, improving the current account balance, and creating tremendous employment opportunities.

6.3 In comparing the economic implications of transporting oil by tankers as opposed to pipeline, the major difference is the fact that first oil can be achieved at a much earlier date with tankers than with a pipeline. Moreover, the employment profile and steel demands for a marine-based scenario are much more gradual over time. The pipeline option has a higher overall purchase requirement and although Ontario is the prime recipient of direct purchases in both instances, the tanker scenario spreads more of its benefits to Quebec and the Maritimes, while the pipeline scenario is most beneficial to the West and Ontario in the early years.

6.4 Dome has recently purchased the Davie Shipyard in Quebec, and is proposing to construct and operate a world-scale shipyard in southern Canada to construct vessels to support development of the Beaufort as well as other major frontier energy projects. Given the opportunity to follow through on its shipbuilding plans, Dome believes Canada will be placed in a uniquely strong position to benefit from this valuable technology.



## 6.0 INDUSTRIAL AND ECONOMIC BENEFITS OF NORTHERN DEVELOPMENT

### 6.1 NORTHERN SOCIO-ECONOMIC CONSIDERATIONS

During the six years that Dome has been active in the Beaufort Sea region, one of the most important guiding principles has been to maximize opportunities for northerners and to minimize possible negative effects of the operations.

Based on several years of accumulated northern experience, Dome, in cooperation with government and the local communities, has been able to develop principles and implement strategies for local participation and benefits which provide visible advantages to the people of the region.

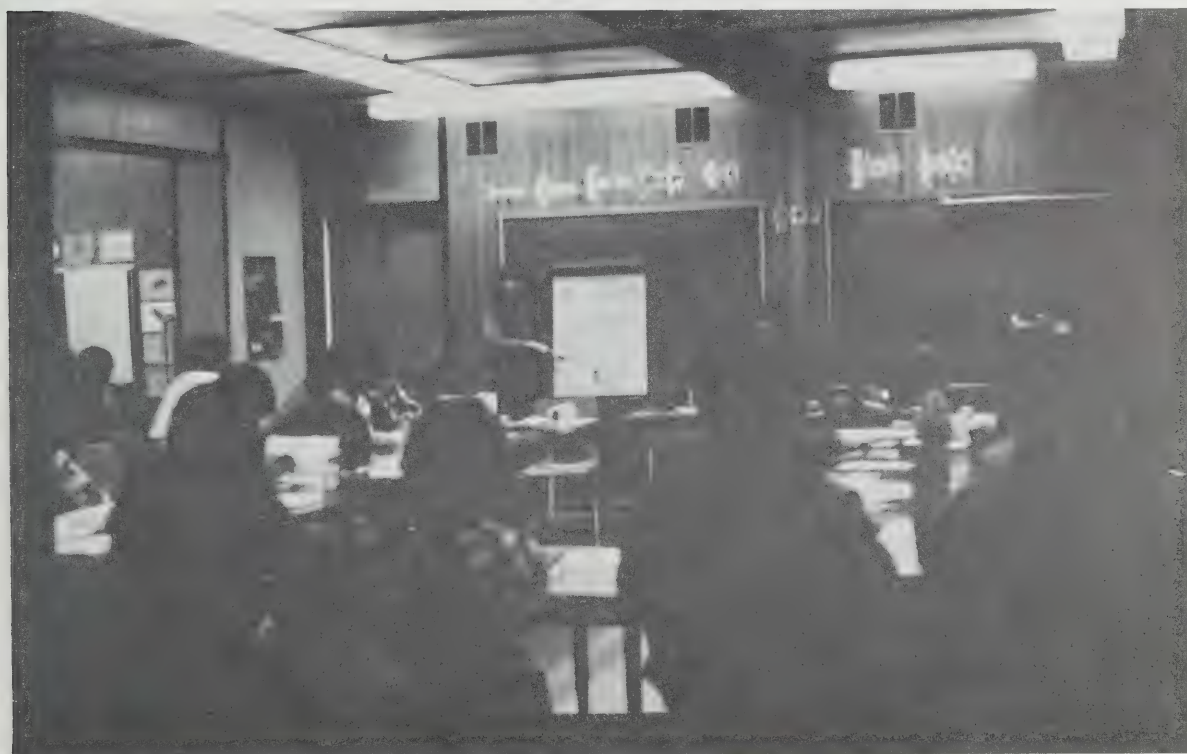
Each year these policies and programs have been described in an Action Plan entitled "Social, Economic, Cultural Agreement, Beaufort Sea Project." The following briefly reviews these programs in the areas of:

- (a) Community Liaison & Consultation
- (b) Northern Employment

- (c) Northern Employee Training & Development
- (d) Economic Development
- (e) Social and Cultural Matters
- (f) Future Development.

- (a) Community Liaison and Consultation

Community liaison and consultation policies have been developed by the company to permit the northern people to participate in planning and operating practices, especially those which bear on environmental, safety, social and economic matters. Dome's policy is to keep northern communities informed regarding their on-going activities, operational problems, and future plans, and to integrate development related concerns and wishes of northern residents into operations and futures planning. Since early in 1976, Dome has promoted liaison with the seven Beaufort Sea communities through a representative body called the Beaufort Sea Community Advisory Committee (BSCAC). The role of the BSCAC is to advise, evaluate, review, and report on the company's activities as they affect the local population. The Committee provides a two-way communication between local residents and the Beaufort exploration industry with emphasis on social, economic, and environmental aspects. The BSCAC has been instrumental in promoting northern employment and training, local business involvement, and environmental protection.



**PLATE 6.1.1** *Dome's policy is to keep the northern communities informed of all ongoing or proposed activities, and to solicit feedback which will be used to mold operations and future planning.*



**PLATE 6.1.2** *Coppermine Meeting — The Beaufort Sea Community Advisory Committee meets every four months in a different community of the Beaufort region in order to discuss Dome's plans and the ways in which the communities can maximize benefits from the industrial activity.*



**PLATE 6.1.3** *The Beaufort Sea Community Advisory Committee has participated in tours of several offshore and/or northern production areas in order to obtain a better understanding of future hydrocarbon development in the Beaufort Region. Here they were visiting the Shetland Islands where North Sea production development has taken place.*

To assist the decision-making process of both industry and government, the BSCAC has developed an education or an awareness process to understand Beaufort oil and gas developments, by comparing it with other areas which have experienced large scale resource projects. There are many recent development examples appropriate to the Beaufort area where industrial projects have helped to enhance the quality of life without adversely affecting social and environmental conditions. For instance, Alaska's Prudhoe Bay and Shetland's Sullom Voe projects are two major petroleum developments that demonstrate the many advantages which can be gained through industry-government agreements.

In March 1981, seven representatives of the BSCAC travelled to the North Sea, England and Scotland, on a study tour of oil and gas developments in the area. The group visited onshore and offshore oil and gas production facilities as well as the northern Shetland Islands where North Sea oil development has taken place. In addition, several study tours have been made to Alaska to visit oil and gas production facilities in Kenai and Prudhoe Bay. The information obtained from these tours has helped the northern people to gain a better understanding of future oil developments in the region.

Dome also participates actively in several other information-type programs.

Company representatives visit with the local community

councils, residents, and native organizations in the Beaufort/Delta area, the Mackenzie Valley, the Yukon Territory, and the Eastern Arctic communities on a regular basis. In addition, over the past four years approximately 400 residents and local government personnel of the seven Beaufort/Delta communities have toured Dome's onshore and offshore operations to have a first hand look at the exploration program. The company has expanded its Inuvik office to accommodate an Information Centre, and during the operating season, a second Information Centre is operated out of Tuktoyaktuk.

With regard to regional and/or futures planning, Dome personnel attend all of the regional planning meetings, in Tuktoyaktuk with the Major Development Planning Committee, and in Inuvik with the Petroleum Planning Committee. A member of the company's Northern Affairs group also attends the Inuvik & District Chamber of Commerce meetings, and the company is represented at most of the Tuktoyaktuk Hamlet Council meetings.

#### (b) Northern Employment

Dome's policy has been to involve northern residents who wish to participate in Beaufort Sea exploratory operations by offering an acceptable balance of employment amongst communities, ethnic groups, and female residents of the Beaufort Sea/Delta communities, the remaining NWT regions, and the Yukon Territory. At the same time, the company is striving to develop a broad base of competently



**PLATE 6.1.4** Information offices have been established at Inuvik, Tuktoyaktuk and Frobisher Bay. Information Officer Abe Okpik from Frobisher Bay will visit many communities in his area over the next year presenting material on the oil industry's Environmental Impact Statement.

trained northern employees for all levels of responsibility while trying to serve the needs of the local communities, governments, and service industries.

Dome's objective has been to maximize northern employment and to increase the number of northern employees in semi-skilled and skilled positions. In 1981, for instance, the company's goal was to employ a minimum of 230 northerners in full-time positions; this was exceeded by 13. A total of 389 northern residents were employed in 243 full-time seasonal and permanent jobs. (See Table 6.1.1) This represents 22% of the total complement of 1,086 positions. An additional 179 positions were filled by contract personnel from the north.

#### (c) Northern Employee Training and Development

Dome Petroleum has set a very high priority on education and training in the Western Arctic. Realizing the mutual benefits to both the employee and the company through the development of a skilled and stable northern workforce, special efforts have been made to address the specific needs of the northern employee in regard to training and job progression.

A combination of vocational and technical training as well as competency based, on-the-job training programs are provided. In conjunction with the Federal Department of Employment and Immigration, northern trainees attend

<b>NORTHERN EMPLOYMENT Comparison 1976 to 1981</b>						
	<b>1976</b>	<b>1977</b>	<b>1978</b>	<b>1979</b>	<b>1980</b>	<b>1981</b>
<b>1. TOTAL NUMBER OF NORTHERNERS HIRED</b>	<b>127</b>	<b>194</b>	<b>181</b>	<b>224</b>	<b>338</b>	<b>389</b>
<b>SKILLED</b>	<b>6</b>	<b>19</b>	<b>33</b>	<b>66</b>	<b>86</b>	<b>109</b>
<b>SEMI-SKILLED</b>	<b>16</b>	<b>58</b>	<b>50</b>	<b>47</b>	<b>86</b>	<b>95</b>
<b>UNSKILLED</b>	<b>105</b>	<b>117</b>	<b>102</b>	<b>111</b>	<b>166</b>	<b>185</b>
<b>2. NUMBER OF REGULAR FULL-TIME POSITIONS</b>	<b>76</b>	<b>97</b>	<b>98</b>	<b>130</b>	<b>194</b>	<b>243</b>
<b>SKILLED</b>	<b>6</b>	<b>19</b>	<b>21</b>	<b>21</b>	<b>40</b>	<b>73</b>
<b>SEMI-SKILLED</b>	<b>16</b>	<b>34</b>	<b>28</b>	<b>29</b>	<b>51</b>	<b>58</b>
<b>UNSKILLED</b>	<b>45</b>	<b>38</b>	<b>36</b>	<b>61</b>	<b>30</b>	<b>112</b>
<b>3. COMPLETED THE SEASON</b>	<b>35</b>	<b>73</b>	<b>83</b>	<b>120</b>	<b>145</b>	<b>230</b>
<b>RESIGNATIONS</b>		<b>66</b>	<b>63</b>	<b>57</b>	<b>90</b>	<b>86</b>
<b>RELEASED</b>		<b>35</b>	<b>19</b>	<b>25</b>	<b>43</b>	<b>51</b>
<b>CASUAL LAY-OFFS</b>		<b>14</b>	<b>20</b>	<b>18</b>	<b>15</b>	<b>22</b>
<b>4. FEMALE EMPLOYEES</b>	<b>16</b>	<b>26</b>	<b>33</b>	<b>38</b>	<b>44</b>	<b>55</b>
<b>5. TOTAL MAN-DAYS</b>	<b>4,650</b>	<b>13,540</b>	<b>14,718</b>	<b>16,718</b>	<b>17,991</b>	<b>(22,000 approx.)</b>
<b>6. TOTAL EMPLOYMENT INCOME (\$000's)</b>	<b>400</b>	<b>800</b>	<b>1,150</b>	<b>2,050</b>	<b>3,500</b>	<b>(7,500 approx.)</b>

**TABLE 6.1.1** Northern employment — Comparison 1976 to 1981.

The 1981 total represents a 20% increase over the full-time positions filled by northern employees in 1980. The 243 full-time positions includes 30% skilled, 25% semi-skilled, and 45% unskilled. To assist in matters related to employment, a Northern Employee Relations Officer and Assistant Officer are responsible for recruiting, hiring, and co-ordinating the Northern Employment Program. On-site Crew Managers assist in the program as well. Northern employees are transported directly from their home communities to their job site. A local resident from each Beaufort community is contracted by Dome to expedite the northern employees on their crew change day; and a Human Relations Advisor is available to offer counselling service to all employees, beyond the on-going liaison provided by the line supervisors and the Employee Relations staff.

courses in such disciplines as roughneck, crane operator, environmental protection, and dredging training.

The Government of the Northwest Territories Departments of Education and of Economic Development, combined with the Federal Department of Employment and Immigration and Dome Petroleum have developed and operate a vocational training school at the company's base camp. The courses offered are an extension to those at A.V.T.C. in Fort Smith, but use locally available resources and facilities for trainees from the Beaufort/Delta communities.

The vocational training school became known as 'Tuk Tech' and offers courses in heavy equipment, basic office practice, and basic seamanship. In 1980, 39 of the 42



**PLATE 6.1.5** *Special efforts have been made to train northerners so that they can make a major contribution to the Beaufort operations.*

students enrolled successfully completed the course. In 1982, courses being taught include pre-employment mechanics, carpentry, and welding, food services, basic office practice and Seamanship - levels 1 and 2.

Dome is committed not just to employing northern residents, but to developing a northern workforce capable of functioning fully and independently in a wage employment environment. Therefore, a basic life skills program is given to the northern employees. This includes training in matters related to money management, home management for working mothers, job attitude, self-fulfillment, grooming and nutrition, etc.

Firewood Studios in Inuvik are contracted to provide northern social/cultural seminars at Dome's base camp aimed at providing the southern employees with a better understanding and appreciation of the history of the north, the people, and the environment.

Northern employees are also granted a special leave program to accommodate traditional hunting/trapping activities.

In summary the northern employment and training program has resulted in the establishment of a stable workforce of northern residents. They have continued to acquire new skills, have grown with the operation and are contributing to the success of Beaufort development. Training programs are continuously being developed and expanded to assure northern employees an ever increasing role within

the company and a secure and challenging career as they participate in this energy field.

#### (d) Economic Development

During the past six years, Dome has been a major factor in the economy of the Beaufort/Delta region. Its business and employment programs have had a strong impact on local economic development, on the availability of goods and services, and on the quality of the labour supply.

Since 1976, Dome has fostered and encouraged a great number of small businesses which provide support services and materials to the company's exploratory operations. In 1981, for instance, Dome paid \$19.3 million to 164 locally based businesses in 15 northern communities (Table 6.1.2). In addition, \$9.7 million was paid to nine 'large businesses' based in the south with branch offices in the north. Nine businesses were used from the Yukon Territory with a total expenditure there of \$1.8 million.

Over the years, the number of northern contractors and the volume of business have increased. Northern contractors are now primarily located in Inuvik and Tuktoyaktuk due to the proximity to Dome operations, and the more diversified economic base of the communities. In 1981, Dome purchases from local businesses in Inuvik and Tuktoyaktuk accounted for 82% of total purchases from locally owned businesses, compared with 45% in 1976 and 51% in 1977. This reflects the rapid growth of the business community in Tuktoyaktuk, and the expansion of the business

**TABLE 6.1.2**  
**COMPARISON, BUSINESS EXPENDITURES, 1977-1981**

	1977		1978		1979		1980		1981	
	Expenditure	Co.	Expenditure	Co.	Expenditure	Co.	Expenditure	Co.	Expenditure	Co.
	(in '000 DOLLARS)									
LOCAL BUSINESS IN										
TUKTOYAKTUK	370	23	1,364	25	2,204	26	3,617	27	6,238	29
INUUVIK	800	48	1,312	53	3,252	68	6,100	71	9,666	80
AKLAVIK	30	3	53	2	157	2	351	2	36	3
PAULATUK			11	1	2	1	2	2	4	1
COPPERMINE			6	2	8	3	9	3	11	3
SACHS HARBOUR					2	1	2	1	5	2
HOLMAN ISLAND					1	2	3	3	4	
FORT McPHERSON					40	1	99	1	132	2
HAY RIVER	340	2	375	4	565	12	776	8	1,815	23
YELLOWKNIFE	750	2	1,992	4	2,116	16	570	12	1,442	13
OTHER					3	3	1	2	23	6
TOTAL	\$2,900	77	\$5,041	91	\$8,400	135	\$11,530	132	\$19,381	164
NORTHERN BASED COMPANIES BASED IN THE SOUTH										
MARINE SERVICE CO.	7,560	3	4,270	3	7,911	3	9,353	3	6,000	3
AIR SERVICE CO.	750	4	2,557	5	501	6	983	4	3,700	6
TOTAL	\$8,310	7	\$6,826	8	\$8,412	9	\$10,336	7	\$ 9,700	9
YUKON BUSINESS							\$ 829	6	\$ 1,565	9
TOTAL NWT & YUKON							\$12,695	6	\$30,646	182

**TABLE 6.1.2** Comparison of northern business expenditures by Dome, 1977-1981.

community in Inuvik.

The G.N.W.T. Economic Analysis of Dome's Beaufort Sea operation indicated the economies of Inuvik and Tuk have expanded in direct relation to the increased Dome activity. As the company expanded activity in its Beaufort Sea program and implemented and emphasized northern hiring and purchasing programs, the economy of the area has improved. Many new businesses have opened. Social assistance payments for economic reasons have decreased, and available jobs in the Delta region have increased. Today, Tuk has an active business community providing many specialized services to the company.

Impacts on other communities in the region are felt mainly in direct wage employment of residents who work in the Beaufort Sea operations. In order to stimulate a broader distribution of Beaufort oil and gas development, Dome has proposed a plan to the seven Beaufort Sea communities to offer a share of the shorebase support facilities to the local councils. This partnership proposal with Dome and the seven local communities would not only provide financial benefits, but would be structured in a manner to allow people to directly participate in the management of the shore facilities. The Mayors of Aklavik, Inuvik, and Tuktoyaktuk visited Alaskan native development corporations

in Anchorage and Prudhoe Bay on August 11 and 12, 1981, to discuss with those groups their experience in ventures with multi-national oil companies who are operating from the north slope of Alaska. Dome's partnership proposal is currently under review by the community councils as well as by the Territorial government.

In summary, participation by the Northwest Territories in the company's operations has increased greatly over the years as more N.W.T. residents are working for Dome, more residents are starting or expanding businesses in response to increased Dome purchases in the N.W.T., and more northern residents are being trained for a wider range of jobs.

#### (e) Social and Cultural Support

The Beaufort Sea Region has been the locale of renewable resource harvesting since the beginning of time. Currently, the local native economy is of mixed character; native people work for wages and use a portion of their income to purchase capital goods for a land-based lifestyle. Dome recognizes the importance of continuing and strengthening the traditional hunting/trapping/fishing economy. Such an economy will continue to offer regional residents a genuine alternative to industrial employment. Of equal



**PLATE 6.1.6** Dome recognizes the importance of the traditional hunting/trapping economy and grants special leave to northerners to accommodate these interests.



**PLATE 6.1.7** In 1981, Dome and the Government of the Northwest Territories worked together to build this 20 million gallon drinking water reservoir for Tuktoyaktuk. Sand was provided from the harbour with the Aquarius dredge, while the reservoir was shaped with earthmoving equipment managed by the GNWT government.

importance, is the lifestyle and heritage of the northern people to provide unity and strength to the culture.

Therefore, since 1976, the company has implemented social and cultural programs designed to ensure that the oil and gas-related activities would be carried out in a manner that would not compromise the long-term harmony and viability of northern traditions. In terms of social support, to reduce the impact of the Dome base camp on the Tuktoyaktuk community, a dry camp policy and controlled access of Dome employees into Tuk was instituted and remains in effect.

Monetary and staff support have been provided for such things as the Tuk Day Care Centre, the Tuk Broadcasting Corporation, Tuk Alcohol Education Programs, and recreation activities.

The presence of Dome in the community of Tuktoyaktuk does put a strain on the local infrastructure and the company responds to this impact by working jointly with the Council on work projects such as garbage dump and road maintenance, power supply, and communication improvements. Dome provided the use of its Aquarius dredge at cost to the N.W.T. Government for the construction of a new water reservoir for the community and industry. Dome provides the facility for the operation of a banking service during its operating season, as well as providing accommodation for the bankers.

The objective of the company's involvement in cultural programs has been to work with the communities, to identify needs and to establish priorities so that assistance can be provided whereby traditional lifestyles and the northern heritage can be strengthened.

In 1981, for instance, \$96,622 was provided in monetary donations to northern communities. The Tuktoyaktuk and Inuvik Councils each received \$30,000, and the Aklavik Council received \$10,000 for various community projects. An additional \$44,500 in material and services was provided to other programs such as the Northern Games held in Fort McPherson in July; World Dog Racing Champion, Peter Norberg; curling, volleyball, and hockey teams; and other recreational and school activities. New playground equipment was donated and installed for the Tuk Mangiluluk school.

Since May 1981, Dome Petroleum has been sponsoring the Canadian Champion cross-country skiers, Sharon and Shirley Firth, from Inuvik, N.W.T. The company has committed \$40,000 to their ski training and competition endeavours in exchange for ski clinics and training programs which they will provide to local residents in the Beaufort/Delta communities. In September, Sharon and Shirley participated in Careers Day in the high school in Yellowknife with three of Dome's Employee Relations Staff. In October, the girls gave dry-land ski clinics for the schools in Inuvik, Aklavik, Fort McPherson, and Arctic Red River. They competed very strongly in the recent

World Championships held in Norway in February, 1982 and hope to represent Canada in the 1984 Olympics. Their long-term objective is to help develop and train northern champions for the Canadian Ski Team for the 1988 Olympics in Calgary.

#### (f) Future Development in the Beaufort Sea

During the next two decades, Beaufort Sea operations will change from seasonal and medium-scale to year-round and large-scale operations. The current Dome socio-economic policies and programs, modified as appropriate, will be applied over the period 1982-2000. Specific socio-economic policies and programs will be formulated in conjunction with specific development plans. There is a tremendous opportunity for beneficial participation and lifestyle improvements for local residents provided that balanced planning, regulation, and controls are implemented now. Several programs were developed in 1981 to begin the process of involving northern residents and government agencies.

To explain future development plans, a possible scenario for Beaufort oil and gas production was prepared by the main operators in the region -DOME, ESSO, GULF - and was released to the general public in July 1981. Regular community visits are made to the Beaufort/Delta area, the Eastern Arctic and Mackenzie Delta to present and clarify this information to the local residents. Slide and other audio-visual presentations have been prepared to assist in describing the proposal to the public. A quarterly magazine 'Beaufort' is being published to further describe the scenario and ongoing developments. Similar information was printed in all of the northern newspapers as a four-part series.

Regarding future employment opportunities, a labour force much larger than can be supplied by the local population will be needed to build and operate all of the facilities which will eventually be required. As the labour force expands, an increasing proportion of it would be needed year-round rather than on a seasonal basis. By July 1981, industry had developed a 'Manpower Plan and Delivery System' in conjunction with the engineering scenarios for development.

The skills required for future developments will vary from very specialized engineering and scientific skills to the more routine labour type skills. In July 1981, the Regional Government for the Western Arctic and industry began to develop a 'Five Year Action Plan' to ensure that education systems in the Inuvik Region would meet the needs of the communities, the individuals, and industry. In September, this was presented to nine Beaufort/Delta communities, the MLA for the Western Arctic, and the GNWT Minister and Deputy Minister of Education. The three main components of the Plan include:

- Vocational training in the high school
- Adult education (up-grading) in all of the



**PLATE 6.1.8** Sharon and Shirley Firth, the Loucheux Indian twin sisters from the Mackenzie Delta community of Inuvik are Canada's premiere cross-country skiers. Here Sharon is being greeted at the Calgary airport before travelling on to a competition.



**PLATE 6.1.9** The oil industry is examining how oil and gas activity may affect the traditional economy of the native people, and how these people can participate in oil and gas development while maintaining their traditional ways.

communities

— A vocational/technical school in Tuk or Inuvik

In November 1981, the EARP Panel began its process of publically reviewing the plans for future Beaufort hydrocarbon development. The seven member panel held meetings in five Western Arctic communities, three Eastern Arctic communities, and three southern communities. The development scenario was once again presented to the participants of the meetings and the residents were given an opportunity to comment on the concerns and questions which they would like the companies to address.

The three proponents in turn, are preparing a detailed description of the technical, environmental, and socio-economic issues associated with future oil and gas development. An important part of this statement is the Social Impact Assessment which includes such basic components as: predictions of community impacts; regional and/or community planning possibilities; income and expenditure effects; and an analysis of the effects of industrial development on resource harvesting. This Environmental Impact Statement will be released by the companies in the spring of 1982 for review by the panel, the government, and the communities. The preparation of the EIS is supported by an on-going information exchange process being conducted with the local communities in conjunction with other consultation programs already in place. Three local residents, one each from Inuvik, Yellowknife, and Frob-

isher Bay, have been retained by the EIS participants to represent their interests and to obtain feedback from the communities in the Beaufort, Mackenzie Valley and Eastern Arctic regions, respectively.

Dome views the Environmental Assessment and Review Process as an essential step which must be taken. It, along with others, should contribute significantly to ensuring a bright future for northerners and the north.

## 6.2 IMPACTS OF MARINE BASED DEVELOPMENT ON THE CANADIAN ECONOMY

This section of the submission describes some of the more important economic benefits projected to be derived from future Beaufort Sea hydrocarbon development. The projections are naturally contingent upon Beaufort development proceeding, and for this presentation a generally high rate or scenario of production activities has been chosen for examination. To reiterate from Section 3.4, the pace of actual development will likely be lower than that projected here, resulting in lowered projections for some of the factors considered. Nevertheless, any development of the Beaufort will carry with it significant economic benefits to Canadians, as evidenced by those derived from the current exploration phase.



**PLATE 6.1.10** Opening session of the Federal Environmental Assessment guideline hearings, in Aklavik, N.W.T., on November 4th 1981. The EARP hearings will help to shape future development and in particular, ensure that a high standard of environmental protection is maintained, and that the benefits for the northern people are maximized.

#### (a) Present Exploration Program

Considerable expenditures have been incurred in support of Dome's present and ongoing exploration program. As an example, in 1981 total capital and operating expenditures for the Beaufort program were in the order of \$482.0 million. Of the total, approximately \$365.9 million, or 76 percent was expended in Canada. Approximately 88% of the \$313.3 million in operating expenditures was spent in Canada on Canadian goods and services. This expenditure is estimated to have resulted in more than \$825 million of Canadian income when multiplier effects are considered.

Of the \$168.5 million spent on capital expenditures, \$90.7 million was spent in Canada creating an impact on the Canadian economy of \$272 million. Capital items which have been purchased or constructed in Canada over the past few years have included many of the supply boats, tugs and other smaller vessels, the Kigoriak icebreaker, the caissons for the Tarsiut island, the drilling package for Tarsiut and Dome's Tuk base.

For 1982, Dome's overall Beaufort Sea exploration budget is estimated to increase to approximately \$700 million. Dome is committed to Canada and Canadians; as the following describes, the potential benefits anticipated in the future can be very significant.

#### (b) Selected Economic Indicators

Beaufort Sea development activities have been represented economically in a model of the overall Canadian economy for the period 1982 to 2000. Selected indicators of the economic impact of this energy project are shown in Table 6.2.1.

Real growth of 3% or more in the country's annual overall output as measured by Gross National Product (GNP) signals a strong economy. However, an economy wherein Beaufort Sea development is taking place will experience GNP growth which exceeds in every year that strong growth rate level. The accumulated benefit to the year 2000 of increased GNP in real money terms is equivalent to one-half of that year's GNP, or is equivalent to the total value of 1982's GNP. Finally the impact of Beaufort development on Canada's economy could be viewed as adding a minimum of one year's strong growth for every 15 year time span.

The improvement in GNP is not due just to Beaufort originated investment, but also due to major direct employment requirements. The combined impact spreads throughout the economy in the form of increased disposable income, increased demand for consumables, increased total industry investment and so on.

The large surpluses of government revenue over expenditures created by Beaufort development allows governments to readily provide all traditional support costs for

### SUMMARY: CANADIAN ECONOMIC IMPACTS - BEAUFORT SEA DEVELOPMENT, MARINE MODE (\$ BILLION 1971)

Indicator	1981	1990		2000	
	Reference	Reference	With Beaufort	Reference	With Beaufort
GROSS NATIONAL PRODUCT	\$134	\$170	\$ 5 incr.	\$255	\$11 incr.
DISPOSABLE INCOME	\$ 96	\$120	\$ 2 incr.	\$180	\$ 5 incr.
BUSINESS INVESTMENT	\$ 27	\$ 38	\$ 3 incr.	\$ 57	\$ 3 incr.
GOVERNMENT SURPLUS (DEFICIT)*	\$(0.2)	\$( 4)	\$ 13	\$ 70	\$135
CURRENT ACCOUNT BALANCES*	\$6.3	\$(15)	\$10	\$(44)	\$130
CONSUMER PRICE INDEX (1971=1.0)	2.4	4.8	5.2	9.7	9.7-13 <sup>1</sup>
EMPLOYMENT ('000 JOBS)	10,655	12,800	181 incr.	15,100	384 incr.
UNEMPLOYMENT RATE	7.4%	6.7%	3.6%	5.4%	3.6%
EXCHANGE RATE (\$CAN/\$US)	0.8	0.9	0.9+	0.9	0.9+
CURRENT DOLLARS*					

1. AS EXCHANGE RATE MOVES TO PARITY, PRICE INDEX WILL DECREASE.

TABLE 6.2.1 Summary of selected economic impact indicators assuming a high rate of Beaufort Sea development.

resulting social and infrastructure requirements. Additional Government revenues are generated directly in royalties and taxes from increased crude oil production in Canada, and subsequently in taxes from a stronger, more active Canadian economy. Surpluses commence in the late 1980's, and continue thereafter. In the year 2000 for example, the government surplus with Beaufort development is forecast to exceed \$130 billion.

The current account balance is also in a strong surplus position through the forecast period. This measure of Canada's merchandise trade and financial services balances reflects in one sense the impact of backing out crude oil imports, and also indicates the potential benefit of crude oil exporting. For comparison most Canadian economic forecasts (those which exclude Beaufort development) show a continuing current account deficit.

In excess of 380,000 new jobs are created in Canada from Beaufort Sea development by the year 2000. Another way of expressing the employment impact is that 3.7 million man years of employment in Canada are required between now and the year 2000 to support this rate of development. The annual number of people projected to be employed directly in the Beaufort are shown in Figure 6.2.1. The on-site job peak in 1990 of 16,400 people is precipitated by the projected construction of the Dempster lateral gas pipeline for startup in 1992. Beaufort total employment demand is strong and continues to grow throughout the forecast period, reaching 23,600 people by the year 2000. Unemployment levels drop essentially to a "fully employed" workforce when Beaufort development is considered. Unemployment in 1990 for example is forecast to fall to 3.6% of the total labor force. The slower Canadian population growth during the 1990's, coupled with continued Beaufort development-sponsored economic growth for this period will serve to maintain a fully employed workforce. The Canadian economy excluding Beaufort activity is forecast to expect unemployment levels of 5% and higher.

It should be noted, however, that the strong growth initiated by Beaufort Sea development may contribute to certain economic pressures. One is the likely upward pressure that will be placed on the exchange rate, due to the large offshore demand for Canadian currency if oil is exported. A second and related impact is a potential increase in the consumer price index due to a strong consumer demand in a growth economy. If the exchange rate is moved towards parity, the consumer price index will be tempered as lower priced imports help to meet consumer demand. A third area relates to job skills and the available workforce. When a workforce is fully employed, there will likely be skills shortages in some job categories. Government policies can moderate these pressures.

#### (c) Sensitivities

Reducing total crude oil production by over 40%, for example, does not reduce the economic impact by the same amount. For instance, in a development activity sense, the

levels of investment, fields developed, and ships built would be reduced by only 30% over the forecast period. Direct employment requirements are reduced by only 10%.

GNP growth at this reduced level of development is still judged to be strong due to the large direct investment and employment requirements. Government surpluses will still exist at upwards of 60% of their previously reported levels. Job creation in Canada would be approximately 70% of full development impact with unemployment still at close to full employment levels. The current account balance is likely to remain in a surplus position, but would result in less pressure on an upward movement in the exchange rate.

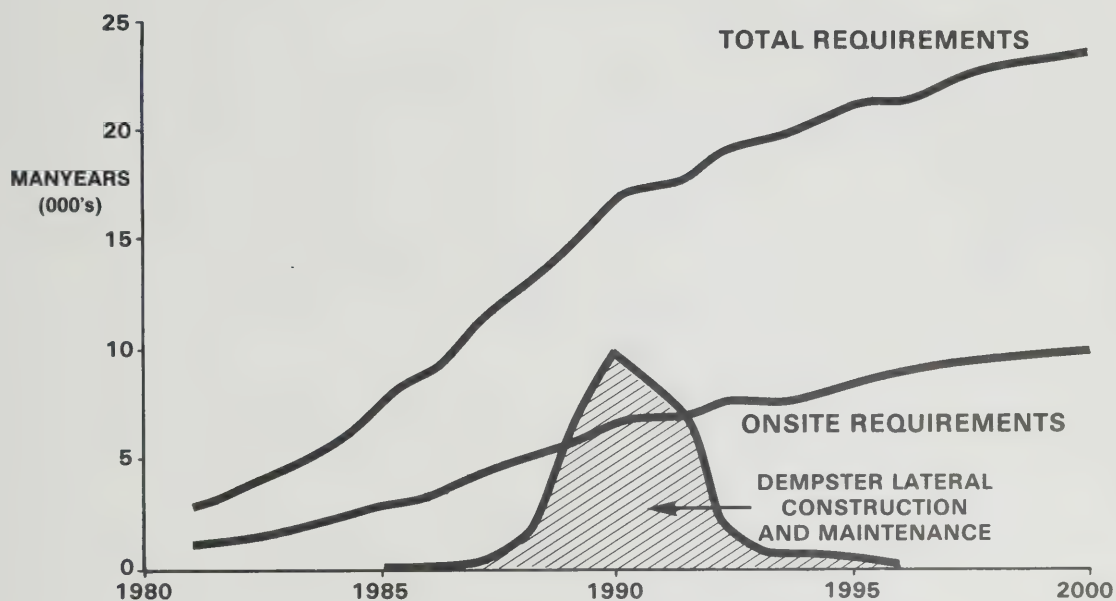
#### (d) Regional Economic Benefits

Beaufort Sea development will have a significant impact on all regions of Canada. The impact in a regional sense is considered here in two ways; the impact of sourcing materials and services from the regions; and the impact of direct employment of people from each region.

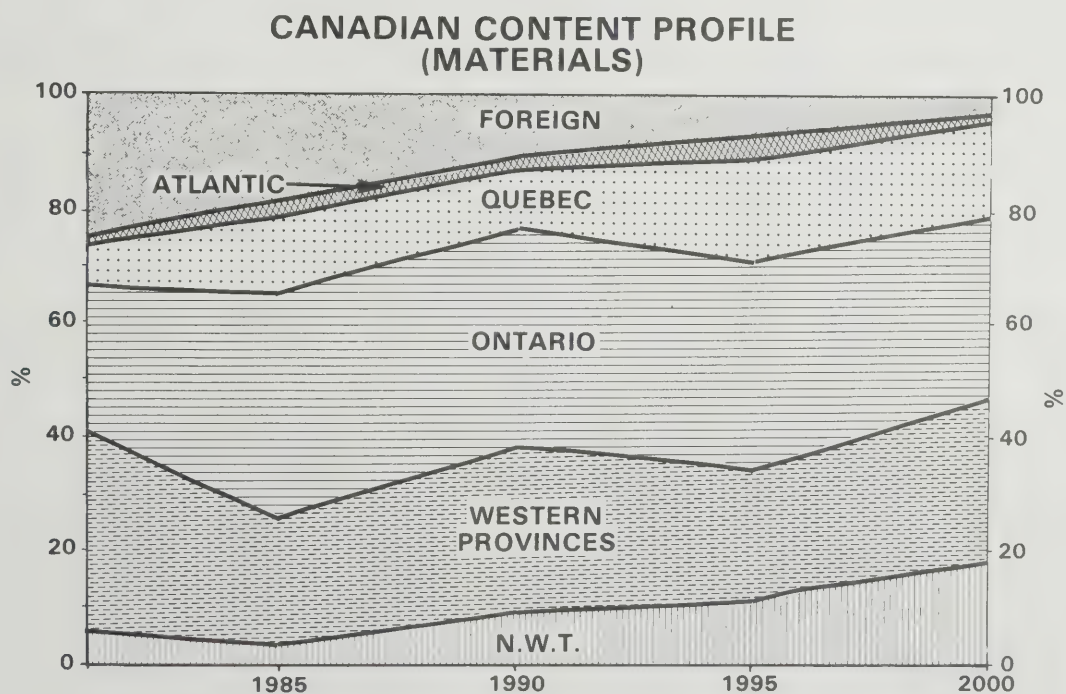
A Canadian content profile has been prepared that targets 85% of total direct purchases for Canada. Canadian content is forecast to rise from about 75% in the early 1980's to over 95% by the year 2000. Figure 6.2.2 profiles the distribution of major materials sourcing in Canada by region and from foreign sources. This profile reflects a continuation of ongoing efforts to source in Canada and to encourage Canada's ability to supply. It assumes an evolving of additional manufacturing and supply capability in Canada in response to the perceived long-term demand for that period. Examples of this would be an expanded shipbuilding capability, and increased steel plate mill capacity.

A total of \$49.7 billion of materials and services are projected to be purchased directly in the Canadian regions to the year 2000. Of this total, approximately \$31.1 billion will be spent on industrial goods. Figure 6.2.3 illustrates the purchases over time and by region. Ontario receives the largest share over the time frame considered, totalling \$9.4 billion dollars, followed by Quebec at \$6.4 billion dollars.

The total impact of the direct purchase of major industrial materials in each region has been calculated with Statistics Canada input/output tables to determine the direct plus indirect values of this activity. As shown in Figure 6.2.4, Ontario, in addition to receiving the largest direct orders, also enjoys the largest indirect impact of regional purchase activity in Canada. This, naturally, is caused by the substantial industrial base in Ontario that has linkages to all other regions in Canada. Also, in 1990 the Prairie region enjoys the second-highest direct and indirect impact. This is due primarily to the significant amount of well casing and oil production goods that are required in the Beaufort which are sourced from the established supply industry in Alberta. However, as noted above, linkages in the supply of this material to Ontario are also evident. Beaufort development will also enhance the economics of less advantaged regions in Canada. The scale of the project and



**FIGURE 6.2.1:** projected annual number of people to be employed in Beaufort development between 1980 and the year 2000.



**FIGURE 6.2.2:** Projected distribution of materials sourcing for Beaufort development.

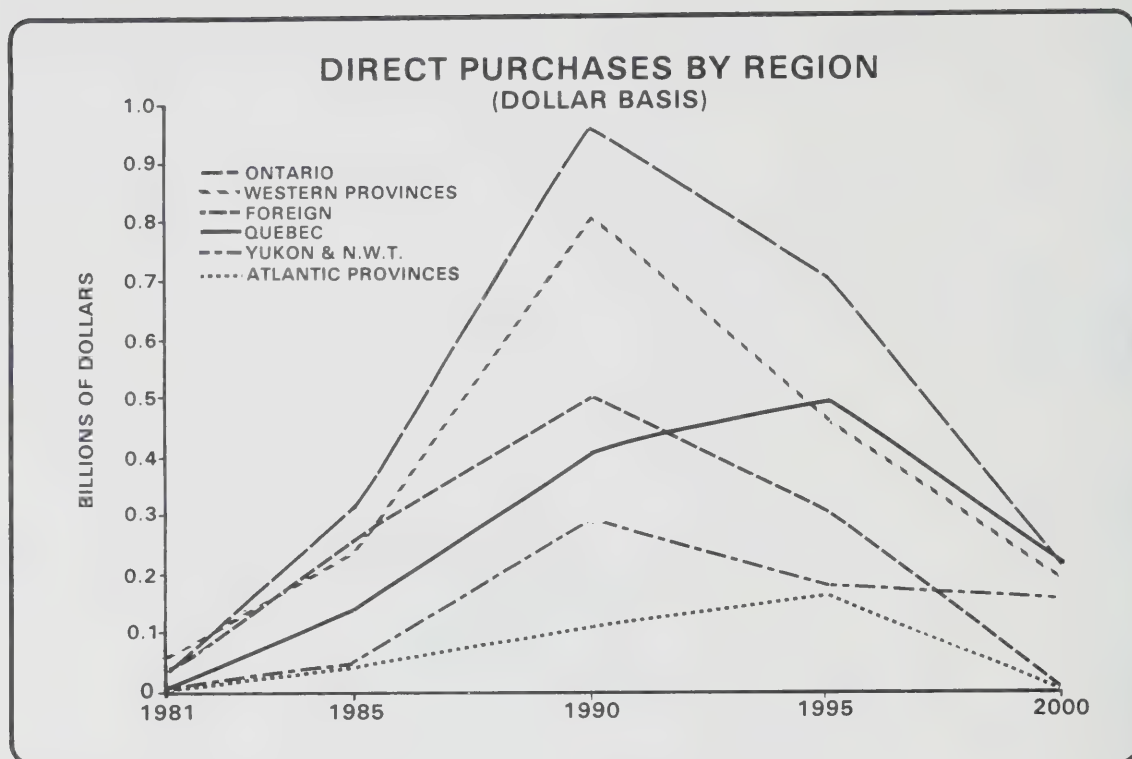


FIGURE 6.2.3: direct purchases for Beaufort development over time by region.

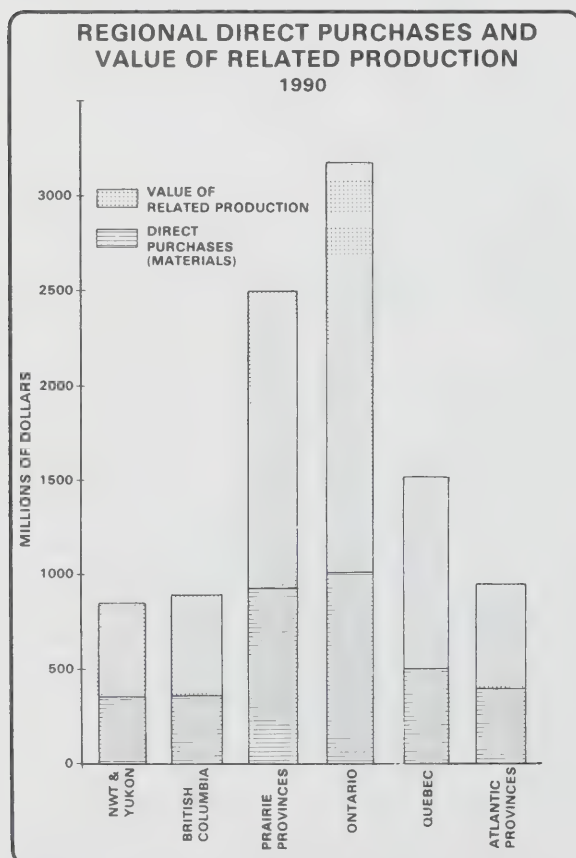


FIGURE 6.2.4: Projected regional direct purchases and indirect values related to these purchases in 1990.

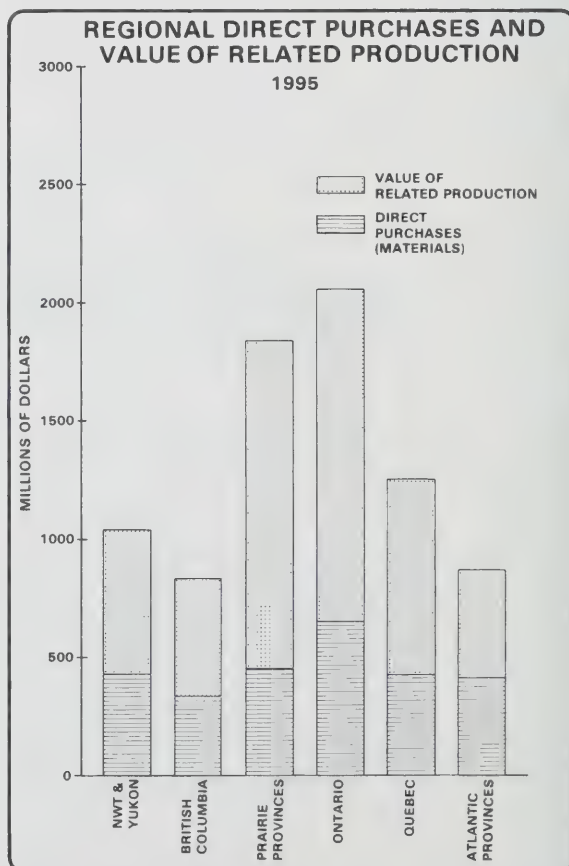


FIGURE 6.2.5: Projected regional direct purchases and indirect values related to these purchases in 1995.

its continuing large magnitude over time will impact dramatically on the Yukon and Northwest Territories. The close proximity of this region to the energy development scene will attract industry and result in a direct growth of manufacturing and services industry capability to meet demand coming out of the Beaufort Sea.

A major part of necessary expansion of Canada's shipbuilding industry to meet Beaufort Sea demand is visualized as occurring mainly in the Atlantic provinces. Shipbuilding spawns large industrial cores in the immediate area. The benefits of increased demand for goods and services will become more pronounced in each of these regions over time as industrial bases mature. This is demonstrated in Figure 6.2.5. Both the Atlantic provinces and the Northern region enjoy a greater share of total output in 1995 than they will in 1990.

The regional employment benefits of Beaufort development are presented in Figure 6.2.6. The direct effects of employment in the Beaufort Sea, as well as the indirect effects due to sourcing, and due to the re-expenditure of Beaufort salaries and wages earned are shown. Ontario enjoys the largest total employment impact of Beaufort development. It should be noted, however, that both Nova Scotia and British Columbia have higher numbers of people directly employed in the Beaufort Sea.

Table 6.2.2 summarizes the impact of Beaufort development on each regions's Gross Domestic Product (GDP), an economic measure of a regions' production output. Once again 3 percent annual growth in GDP is considered by many economists as desirable. Both the Atlantic region and British Columbia — Northern Territories enjoy the highest improvement in Gross Domestic Product. For example, the Atlantic region will see a dramatic increase in GDP of 10 percent over what is forecast without Beaufort Sea development taking place. By the year 2000 the additional growth increases to 25 percent. The impact of large-scale shipbuilding in the region plus the economic benefits of a fully employed population cause new economic plateaus to be established. For British Columbia and the Northern Territories, the results are equally impressive. The benefits in each of the regions reported can be generalized as follows. Quebec gains one year's GDP growth by the year 2000. Direct regional materials sourcing and expanded shipbuilding at Davie are the major reasons for this. Ontario's GDP is very large in comparison to the value of direct Beaufort sourcing in the province. However the industrial linkages with other regions results in a strong overall GDP growth through to the year 2000.

In the Prairie region even today's strong GDP growth is improved by Beaufort activity. By 1990 it shows an

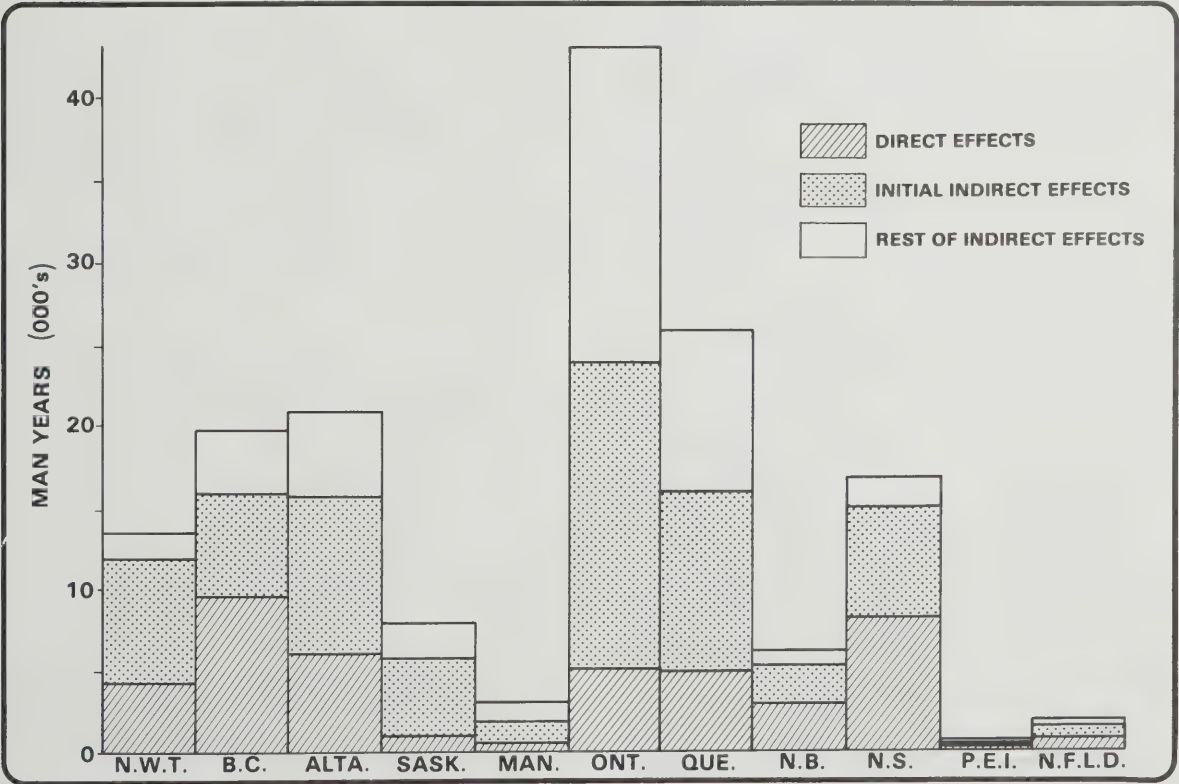


FIGURE 6.2.6: Projected regional employment effects of Beaufort development in 1990.

### ADDITIONAL GDP WITH BEAUFORT

	1980	1990	2000
ATLANTIC	100	+10	+25
QUEBEC	100	+ 2	+ 4
ONTARIO	100	+ 2	+ 9
PRAIRIES	100	+ 4	+ 8
BRITISH COLUMBIA-TERRITORIES	100	+ 6	+20

**TABLE 6.2.2:** Summary of projected impact of Beaufort development of Regional Gross Domestic Product Index.

increase of at least one year's growth in GDP. This expands to the equivalent of two year's GDP growth by the year 2000.

#### (e) Beaufort Development and Government Economic Objectives

The Federal Government presented a white paper in November 1981 entitled "Economic Development for Canada in the 1980's." The white paper brings together the policies of the Government of Canada for national economic development, and states "this policy-frame work will guide the Government of Canada's actions in the coming years."

Beaufort Sea development appears to complement the government's strategic policies and programs in the five priority areas, namely, Industrial Development, Reserves Development, Transportation, Export Promotion, and Human Resources.

#### (i) Government Objectives: Develop Natural Resources: Crude Oil Self-Sufficiency By 1990

- Beaufort Development and the Hibernia Development, both offshore plays, are both at about the same level of developed technology, and are the nearest term new oil supply sources for Canada.
- Beaufort oil production in 1990 if permitted could by itself make up the shortfall in Canadian crude oil supply to meet Canadian demand. Several scenarios are possible, however, including the more likely combined Beaufort-Hibernia oil production contribution.
- Beaufort development is a significant energy project as it represents about 10 percent of the total value of all major projects reported by the Major Projects Task Force.
- Beaufort Development by the tanker mode of transportation would be equally as effective as Hibernia oil development in placing new oil supply to the Eastern region of Canada where imported oil is now used.

#### (ii) Government Objectives: Enhanced Industrial Development from Major Projects: Directed Regional Benefits Where Required

- Beaufort activities historically have had a very high Canadian content for goods and services.
- Beaufort development offers tremendous Canadian industrial supply opportunities. A target of 85 percent Canadian content has been established, a preliminary estimate indicates the sourcing of \$49.7 billion of materials and services in Canada to the year 2000.
- \$9 billion of Beaufort expenditures to 1990 are projected for ship construction and marine structures which can be directed to the Canadian shipbuilding industry on Canada's East Coast, West Coast, and along the St. Lawrence. Thus, economic benefits of Beaufort Development can be maximized by dispersing marine orders to depressed regions and industries where capacity is available.
- Canada's shipbuilding industry is identified as a critical supply deficient industry in relation to Beaufort created demand. Present Canadian capacity could be increased by up to 3 times to meet the annual long term demand. Thus, the Beaufort provides a base demand on which the government can develop long term plans and programs for expansion and upgraded productivity of this industry.
- Dome is proposing a new greenfields shipyard as the most cost-effective way to add shipbuilding capacity for the construction of Arctic Class 10 oil tankers. This will be a world state-of-the-art shipyard that can be located selectively on either Canada's East or West coast to provide maximum benefits to Canada.

More details are provided on this project in Section 6.4 of this submission.

- Dome is proposing to expand the Davie Shipyard to undertake the more sophisticated or outfit intensive Arctic vessels such as icebreakers, large dredges, and drilling systems. This optimizes the use of the existing labour pool inside the shipyard and provides long-term business for the established regional infrastructure around the shipyard.

#### (iii) Government Objective: Increased Technology Infrastructure

- The ice regime in the offshore Beaufort Sea has necessitated the development of new Canadian technology to understand ice behaviour and forces, and to design facilities capable of operating in this ice regime. Dome has established an international team of expertise in Canada to design and test new technology. This is an ongoing program. The latest example is the Tarsiut

caisson-retained test island built in 1981.

- Arctic marine operations require the development of innovative ice reconnaissance systems to determine ice movements, concentrations, and thicknesses along the shipping route. This technology will complement existing Canadian electronics and satellite technology. Research and Development has been initiated by Dome to advance this technology.
- Beaufort marine operations will require new technology to design and construct Arctic class crude carriers that can operate year-round in the northern region. Research and development by Dome to prepare a commercial cost-effective design has been underway for several years now. Prototype scaled down ice-breakers have been built and tested. The latest ship, the Kigoriak has handled level ice up to 6 feet thick. Dome has assembled a team of icebreaker naval architects, and Canada is now acknowledged as a technological world leader in the icebreaker design field.
- Dome's naval architects are now considering a new grade of high tensile low temperature Arctic steel for shipbuilding. This could be developed and tested in Canada.

(iv) Government Objective: Develop and Upgrade Transportation Modes

- Logistics of materials supply to the Arctic have reached a point where the Mackenzie River system is fully utilized. Freight requirements for Beaufort development have been prepared. Alternative modes of supply are now being examined. Private enterprise operators are being encouraged to participate.
- Almost 80% of the substantial direct employment requirement in the Beaufort will be supplied by transporting people weekly from southern Canada. Air services to the north will be expanded and modernized significantly.
- Year-round Beaufort marine oil transportation through the Northwest passage will be established by the late 1980's. Aside from the technological and economic benefits of this activity, a year-round presence enhances Arctic sovereignty, and has strategic military implications for Canada. Additionally, large mineral reserves such as coal, uranium, and iron ore will become better candidates for development by having access to a proven year-round transportation system.

(v) Government Objective: Upgrade Human Resources

- Dome's Beaufort Sea activities have included native training and development programs to maximize employment opportunities in the company's

operations.

- Dome's shipyard development programs include training programs, including special schools, to upgrade skills levels to shipyard standards.

## 6.3 ECONOMIC COMPARISONS, MARINE AND PIPELINE

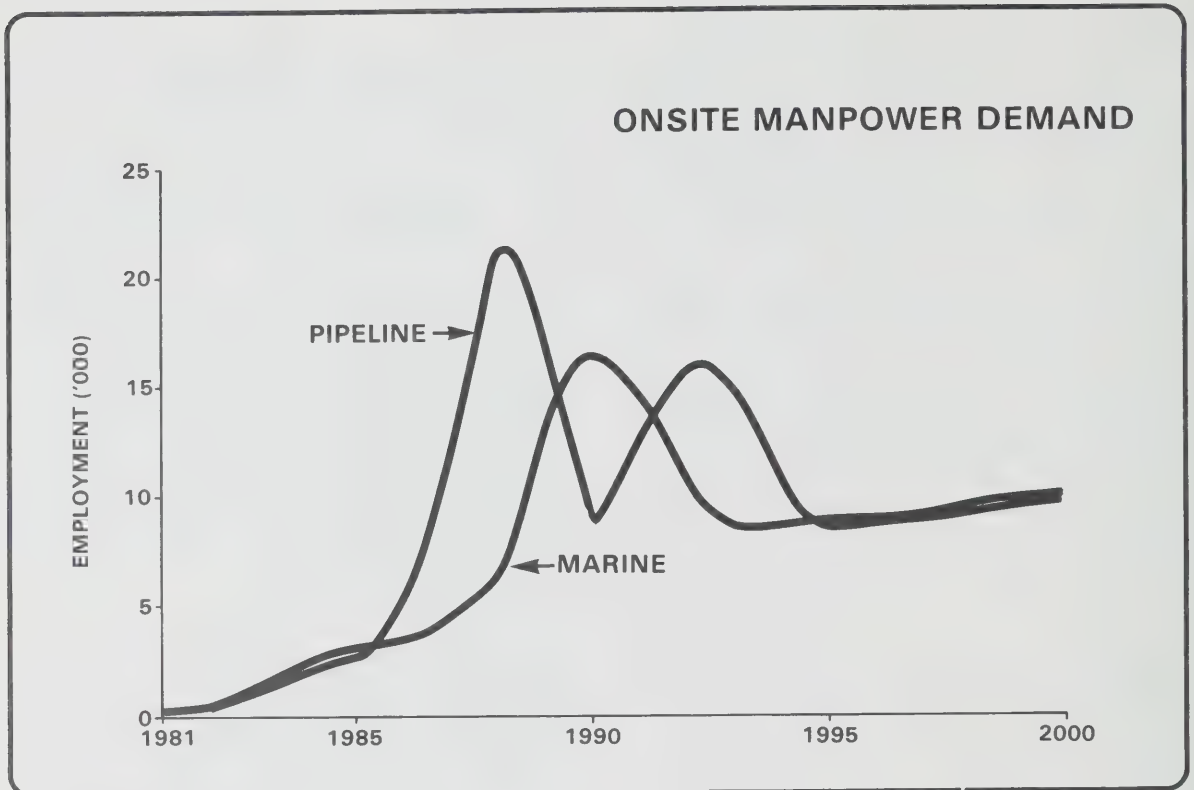
In comparing the marine mode with the pipeline mode, it should be noted that the major difference will be in the rate of development of crude oil production in the first ten years. A marine based Beaufort operation can begin as early as 1985, utilizing a threshold reserves level of as little as 300-400 million barrels. For a pipeline however, the significantly increased threshold of approximately 2.5 billion barrels of recoverable reserves would curtail crude oil production by pipeline until at least 1990. The impact of this difference in timing of development can be demonstrated in several ways.

For pipeline development a significant peaking of employment occurs twice over a ten-year period as shown in Figure 6.3.1. The first occurs during the construction phase of the crude oil pipeline and the second occurs as the Dempster lateral gas line is brought on-line. In comparison, the employment profile for a marine based development is much more gradual in growth, having however to also accommodate the 2 to 3 year demand by 1990 for construction employment associated with the Dempster lateral.

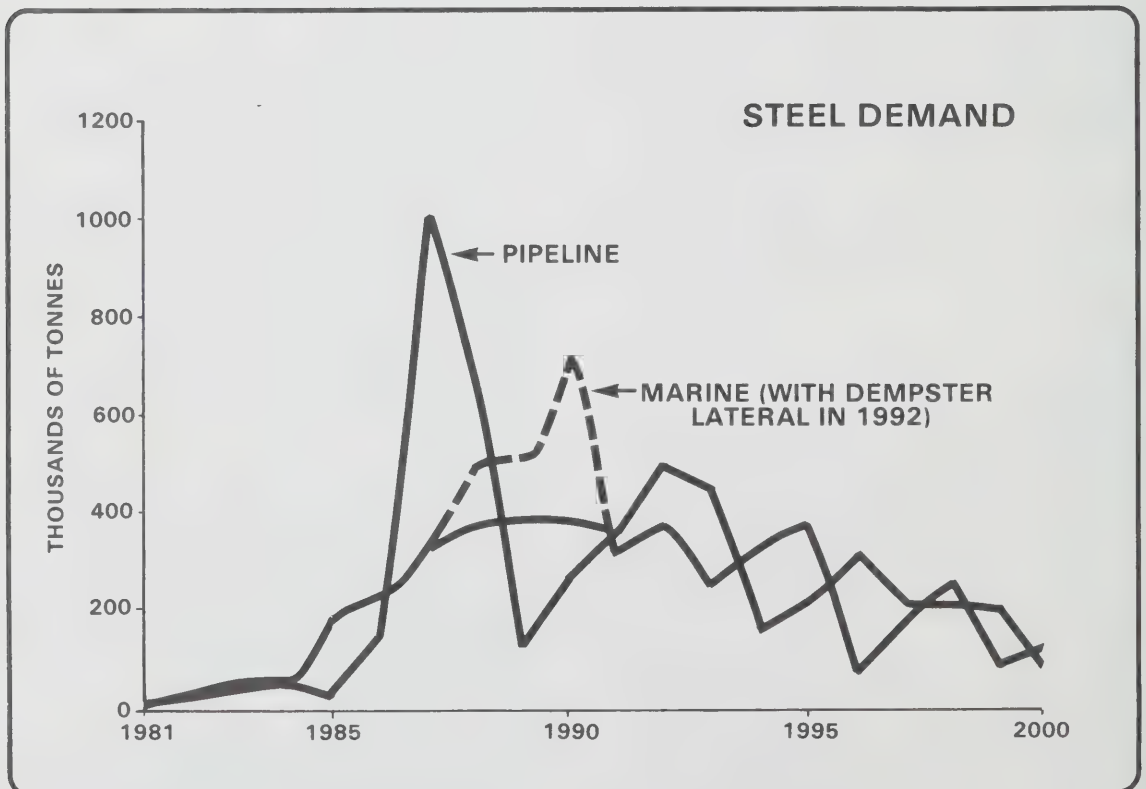
Figure 6.3.2 illustrates the total steel requirement for the two transportation modes. Pipeline steel demand increases dramatically in the early years, primarily for line pipe, to about 800,000 tonnes of steel. Demand then diminishes over time to about 153,000 tonnes of steel after 1995. The marine component, however, has a more gradual build-up to approximately 450,000 tonnes of steel, tapering off to about 350,000 tonnes of steel by 1995. Figure 6.3.3 compares the direct purchases by region for the two modes. There is a slightly higher materials and services requirement for the pipeline option of \$62.2 billion dollars as compared to \$61.1 billion dollars for the marine option. In both cases, Ontario is the prime recipient of direct purchases.

The national econometric impacts of Beaufort development with either of the two transportation modes are generally the same. Both scenarios generate strong economic growth and minimum unemployment over the forecast period. The rapidly initiated development activity following the decision to commence the pipeline causes a slightly higher impact in the early years for this mode. The tanker system appears to create slightly higher benefits in the later years.

On a regional basis the tanker scenario spreads more of its benefits to Quebec and the Maritimes while the pipeline

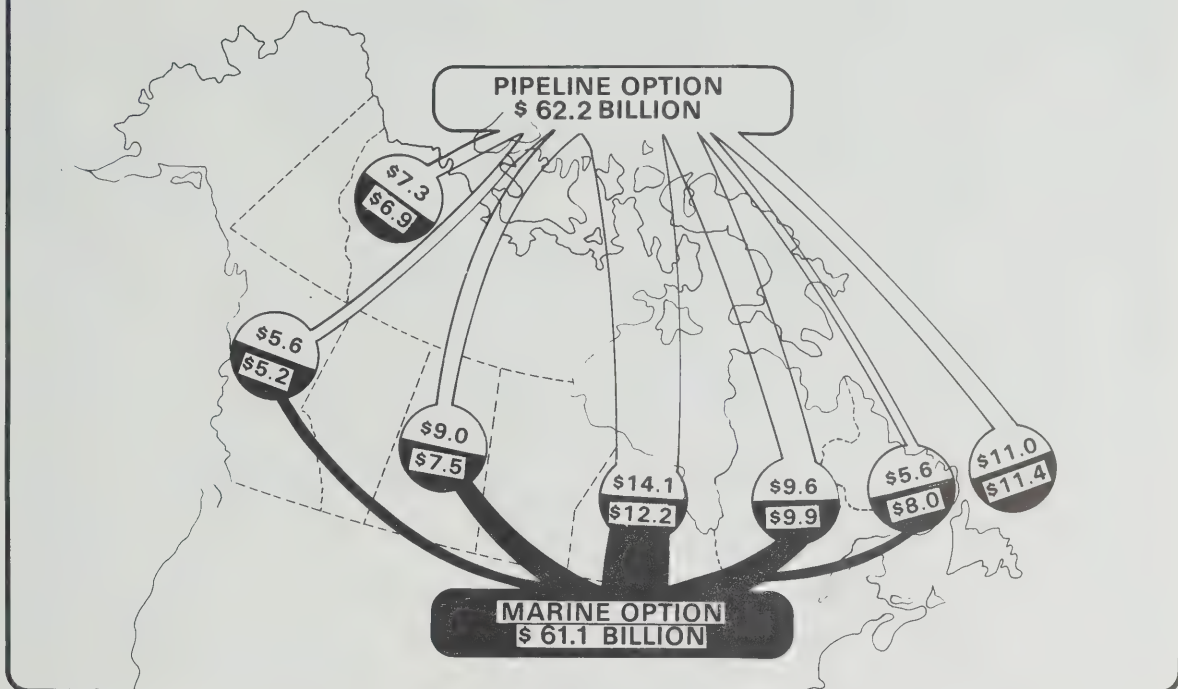


**FIGURE 6.3.1:** Comparison of projected pipeline and marine (tanker) related employment profiles.



**FIGURE 6.3.2:** Comparison of projected pipeline and marine (tanker) related steel demands.

## TOTAL REGIONAL PURCHASES OF MATERIALS AND SERVICES (1982-2000)



**FIGURE 6.3.3:** Comparison of projected direct purchases by region for pipeline and marine (tanker) related activities.

scenario in the early years is more beneficial to the West and to Ontario. In the tanker system, the construction of ships and the supply of marine services from the eastern provinces brings a higher level of prosperity to the region that will not be present in the pipeline scenario. The construction of the pipeline pumps large amounts of revenue and wages into an already strong Ontario and Western Canadian economy because of the labour intensive nature of the project and the demand for pipeline related steel goods.

## 6.4 CANADIAN SHIPYARDS

### (a) Requirements for Vessels and Marine Structures:

The exploration for and development and production of Arctic hydrocarbons represents an important new demand for ships and marine structures regardless of the delivery option selected. Given a marine delivery system, this demand becomes even more significant and of a continuing nature.

Figure 6.4.1 summarizes the ship steel requirements for Beaufort-related marine demand, as well as existing and other projected demand and contemplates the supply impact of expanding Canada's largest shipyard (Davie Shipbuilding -Lauzon, Quebec) plus the addition of two

new large steel-intensive shipyards. This supply scenario recognizes a unique opportunity to supply a major share of projected demand from Canada.

Figures 6.4.2 illustrates the range of vessels required for Beaufort Sea development including a marine delivery system.

The existing Canadian shipbuilding industry has the manufacturing capability to produce small to medium sized vessels. For larger vessels and structures one or more new shipbuilding plants possessing large enough facilities and the specialized equipment necessary to efficiently meet this demand will be required.

### (b) Description of New Canadian Shipyard for Dome

The planned new Dome shipyard is designed to be an assembly facility incorporating the highest levels of proven technology consistent with reasonable operating flexibility. The shipyard's main manufacturing objective is to achieve a high throughput of steel. Thus some outfit manufacture sub-contracting plus the normal procurement of materials and components for the new ships and structures will result in Canadian marine suppliers playing an increasingly important role in Arctic hydrocarbon developments.

The new shipyard will be large not only by Canadian standards but also in world terms. Its annual single shift

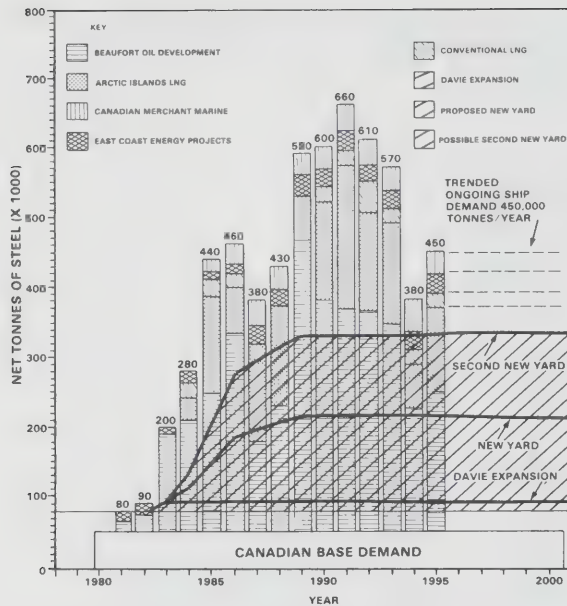


FIGURE 6.4.1 Canadian ship steel requirements 1981-2000. Additional shipyard expansion scenario.

steel throughput capacity will be greater : the annual average of the existing Canadian shipbuilding industry. The efficient handling, preparation, cutting and fabrication of thick, low carbon, high tensile steel in volume is the key to cost effective building of the large vessels and structures required. The operational plan for the shipyard is for a steady state two shifts achieving an annual throughput of 120,000 tonnes of Arctic vessel type steel. In ship terms this equates to one and one-half Arctic Class 10 tankers (200,000 tonnes) per year.

The shipyard will cover approximately 100 acres of land. In addition to the usual offices and amenities buildings, it will include a number of very large shops, up to approximately 50,000 square metres in size. To erect the large steel modules, partially outfitted, will require a building dock 80 m x 520 m in size spanned by a goliath crane able to lift 900 tonnes. The supporting quay, where the ships will be outfitted, other cranes, transport and services will all be proportionately large, specialized and in many instances, unique in Canada.

#### ESTIMATED MARINE SYSTEMS 1981-2000

		SIZE	COST (\$1980) mm	TONNES STEEL	HORSEPOWER
ROUND DRILL SHIP		65 MX 65 M	110	10,000	—
SUPER DREDGE		210 M X 35 M	120	20,000	50,000
SUPPLY BOATS		80 MX 18 M	25	1,700	9,000
AML X-3		80 MX 17 M	40	3,000	12,000
AML X-6		100 MX 22 M	70	6,000	27,000
ACCOMMODATION BARGE		150 M X 30 M	35	5,000	—
ICE BREAKING TANKERS		370 M X 50 M	300	80,000	150,000
STORAGE BARGE		300 M X 70 M	140	70,000	—
PROCESS BARGE		200 M X 60 M	200	20,000	—
DRILL BARGE		150 M X 30 M	80	15,000	—

FIGURE 6.4.2 Projected range of vessels required for Beaufort Sea development including marine delivery system.



**PLATE 6.4.1** The Davie shipyard was recently purchased by Dome and will be used to construct a number of icebreaker ships needed for Arctic offshore operations.



**PLATE 6.4.2** The planned new Dome shipyard, shown in this artist's rendering will be a world-scale operation. It will combine the specialization required to efficiently build large Arctic class vessels, as well as other large steel intensive marine structures.

The new Dome shipyard will be well balanced. The specialization necessary to efficiently build Arctic Class vessels will be combined with a broad capability to meet most other large steel intensive marine requirements.

A high technological level of manufacturing competence is essential to the building of large, steel marine vessels and structures for the Arctic. On a world scale of 4, the better Canadian shipyards are at approximately 2; the new Dome shipyard design approaches 4.

#### (c) Economics of Building New Large Vessels and Structures in Canada

The present Canadian shipbuilding industry relies to a significant extent upon a largely protected domestic market including contracts for the Government of Canada. During times of peak international demand and particularly in special product situations, (for example jack-up drilling rigs), Canadian shipbuilders have successfully exported. However, the export of ships from Canadian shipyards has not been a financial success overall.

The supply of vessels and structures from foreign sources to Canadian owners or to foreign owners for use in Canadian waters has focussed mainly on products which physically or, to a lesser extent, technologically have been beyond the capabilities of Canadian shipyards. There is, of course, always some element of foreign competition even when a particular requirement can be met by Canadian shipbuilding capabilities, especially when the Canadian coasting trade laws do not apply and when delivery and price considerations are keen.

Where Canadian shipyards are physically or technologically limited are matters of genuine concern. Only with the construction of a new, large, world-class shipbuilding capability will the "source in Canada" option become a reality for the majority of the forecast demand.

The technical dimension is always an important competitive element in ship procurement. All too frequently, even for vessels built in Canada, the design and development work for a vessel or structure is done outside the country. Dome is continuing to build in Canada a leading technical ship design team. It would be unfortunate if this important Canadian resource should be limited to supporting foreign shipbuilding, especially in a sector such as the Arctic, where the technology and expertise should be intrinsically Canadian.

The international shipbuilding industry has an important non-manufacturing cost-related competitive dimension—the ship purchase finance schemes. In accordance with the OECD Understandings, to which Canada is a signatory, Canada offers concessionary (interest cost subsidized) export credit to non-Canadian purchasers of Canadian built ships. However, Canada has no government financing scheme to assist *Canadian* interests to acquire vessels

and structures from Canadian sources. Additionally, Canadian tax laws respecting the claiming of Capital Cost Allowances are less generous and flexible than those of other industrially developed nations and Canadian coasting laws, the impact of which is likely to be extended, in certain situations restrict ship procurement.

With Canada's increasing involvement in marine activities off the East Coast and in the Arctic and considering the importance of Canadian sourcing to the whole economy, a critical, missing element is a national scheme which will enable Canadians to finance the purchase of vessels and other marine structures and in a more competitive manner.

A "Canadian for Canadians" vessel and marine structures financing environment could be established by the Government of Canada and might include:

- guarantees backed by first mortgages,
- additional Capital Cost Allowances flexibility,
- debt repayment terms relevant to the hardware and its usage,
- a competitive (not necessarily concessionary) interest rate, and
- a commitment and insurance fee payable by the borrower to build a pool against defaults.

This type of plan could be a major economic tool for government and would encourage projects important to the Canadian and regional economies. These plans could be referenced to specific projects of national importance and for reviewable fixed terms.

#### (d) Benefits for Canada

The linkage of industrial development to natural resource exploitation has long been a Canadian goal, if a somewhat elusive one. Arctic hydrocarbon development offers a fresh opportunity to secure for Canada new technology and to link that new technology directly with the production timetable for these frontier resources. Shipbuilding is an ideal way to obtain and use such new technology.

The plant and equipment, processes and techniques planned for Dome's new shipyard are not individually unique—it is their combination in a single plant and for a well defined product range which is special. Not only will this be a major step in itself, but it will also bring about a quantum improvement in support industries and related skills.

Large vessels for Arctic operations not only will require large steel tonnages but much of the steel must possess special characteristics—low carbon and high tensility. Canadian steel mills have the potential to acquire and use the relevant technology, but in the absence of a firm domestic market are unlikely to develop this capability. Equally important, the specialized welding and other fabrication-related techniques needed for such steels can

only be secured if there is a domestic demand for them. Dome's new shipyard can provide the market and the training ground. Figure 6.4.3 gives an order of magnitude for projected steel demand.

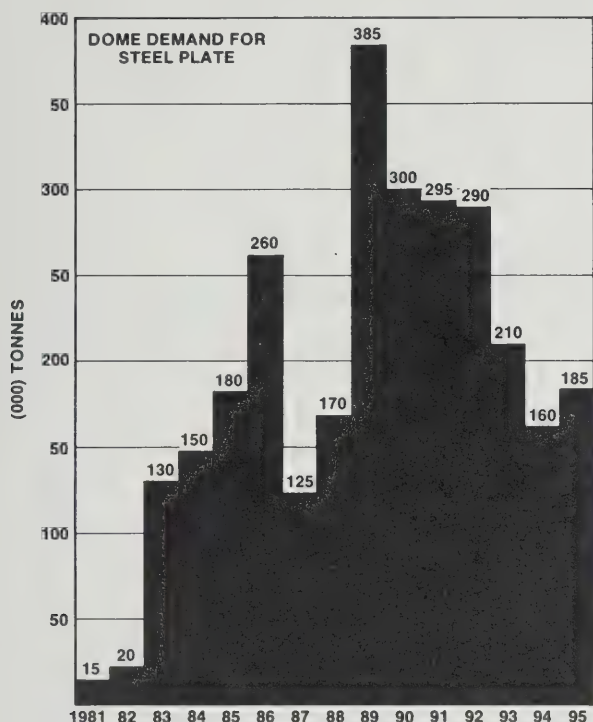


FIGURE 6.4.3 Projected steel demands for Dome projects.

A significant element in foreign competitiveness in ship-building is the marriage of design to production facilities. For some years Dome has been progressively building an important marine design capability for Canada, the key is to now link this to sourcing in Canada. A “produceable” or “production-kindly” high technology design built in a fully competent plant will be a Canadian marine first. Taking this step will roughly double the existing Canadian capability. The opportunities for training to highly-skilled levels with real opportunities for employment are addressed separately.

The projected demand for new large vessels and structures, together with Dome's new shipyards's policy to substantially sub-contract much of the outfit manufacture, provides unprecedented opportunities for Canadian industry, particularly those already established in Ontario and Quebec. Table 6.4.1 compares present Canadian capabilities with the potential in the future. Figure 6.4.4 addresses specifically the machinery and outfit components aspects.

The clear alternative to building these vessels and structures in Canada is to obtain them from abroad. Too frequently this has been the Canadian reality. One clear consequence is the negative impact on Canada's balance of

payments. The magnitude of cost implicit in any of the energy-related mega-projects is such that obtaining virtually all the marine hardware from foreign sources will become an increasing burden on Canada's trading account.

For the most part, successful exporters based in industrially developed countries have had the opportunity to build upon a strong domestic base. Given the technology presently held by Dome and the opportunity to supply new Canadian marine hardware needs from Canada, the potential to export is seen as a next reasonable objective.

(e) Human Resources - Skills and Availability

The large new shipyard envisaged by Dome will require access to a sizeable pool of persons, with basic education, capabilities and a willingness to be trained. As in any major industrial undertaking, key senior and specialist managers will likely come from areas other than where the shipyard will be located.

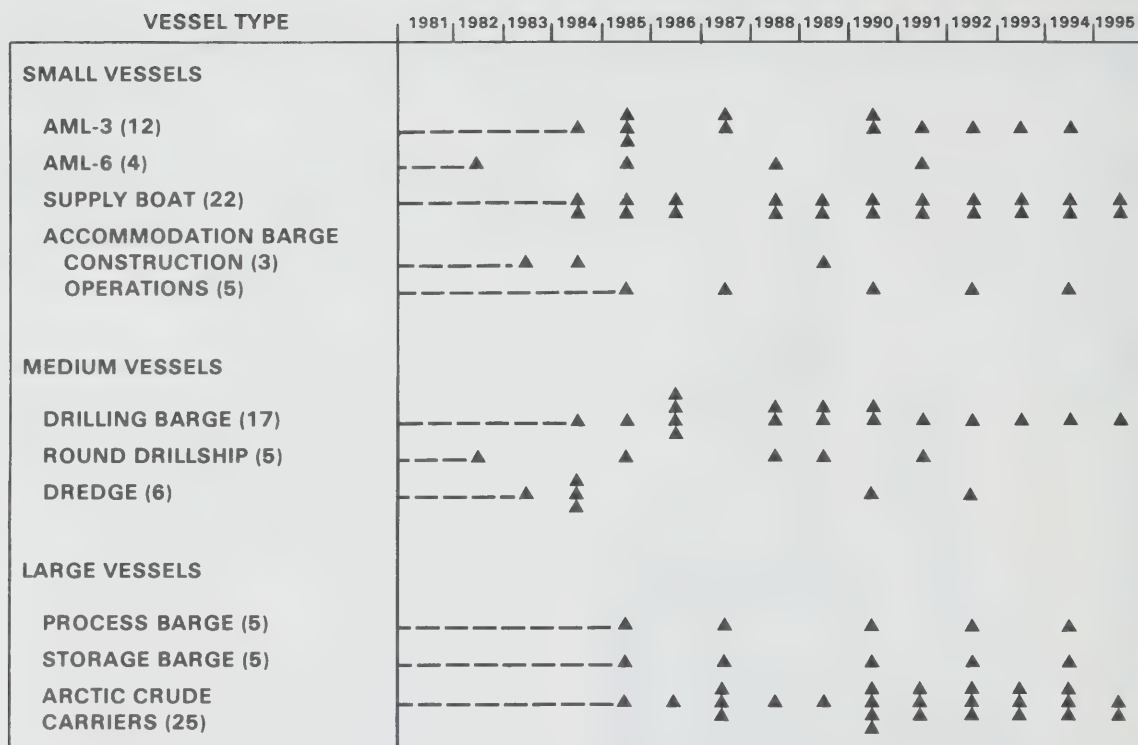
Of all locations examined by Dome as possible sites for a new shipyard, none possess a ready base of appropriately skilled personnel. While it will be necessary to obtain some skilled personnel trained outside of Canada in the shipyard's early stages, the objective from the outset is to train Canadians for all positions. In areas such as accounting, office services and general support positions, Canadians will be recruited without difficulty. For the specialist ship-building areas, ambitious training programs are being formulated.

Figure 6.4.5 graphs the progressive build-up of management, staff and work force to a steady-state, two-shift level. The specific numbers of people making up the workforce are presented in Table 6.4.2.

These training programs will be directed toward both unskilled and skilled persons. In the latter case, the new manufacturing technology will require a skills enhancement program. The plan is to develop a school dedicated to these purposes. It will be fully equipped with modern tools and teaching aids and will cater to 300 trainees at a time. During the early stages, this school will operate on two shifts to quickly build up the shipyard's work force. For completely untrained personnel, the in-school period will be six months. Once the shipyard is fully staffed, training levels will be related to attrition rates and the needs of other potential employers.

In the absence of fully developed Canadian university programs for naval architects and marine engineers, Dome will create a three-month program to “convert” young Canadian engineers into production supervisors. This will be followed later by educational support to further develop this resource.

Also, in the non-shipbuilding areas, such as software systems, training programs will be mounted to develop, for



**TABLE 6.4.1.** Beaufort Sea development program — Multiple fields with phased build-up 1980-1995. Projected as at March 1981.

#### A NEW DOME SHIPYARD

MANPOWER BUILDUP			
YEAR	SHOP FLOOR	STAFF	TOTAL
1981	5	5	5
82	0	25	25
83	0	50	50
84	0	160	160
1985	700	275	975
1986	1150	375	1525
(SECOND SHIFT BUILDUP STARTS)			
87	1500	420	1920
88	1825	465	2290
89	2125	510	2635
1990	2160	510	2670
1991*	2160	510	2670

- STEADY STATE SINGLE SHIFT MANPOWER BY 1985
- STEADY STATE DOUBLE SHIFT MANPOWER BY 1989
- ASSUMES DEMAND PROGRESSIVELY UTILIZES FULL CAPACITY
- NUMBERS ROUNDED AND CALCULATED AT MID-YEAR

#### NOTES

- (1) NUMBERS ROUNDED AND CALCULATED AT MID YEAR
- (2) PROJECTION OF MANPOWER BUILDUP IS BASED ON A & P APPLIEDORE'S DECEMBER 1980 FEASIBILITY STUDY AND SUBSEQUENT DISCUSSIONS

**TABLE 6.4.2** Projected manpower build-up for a new Dome shipyard.

example, high school graduates.

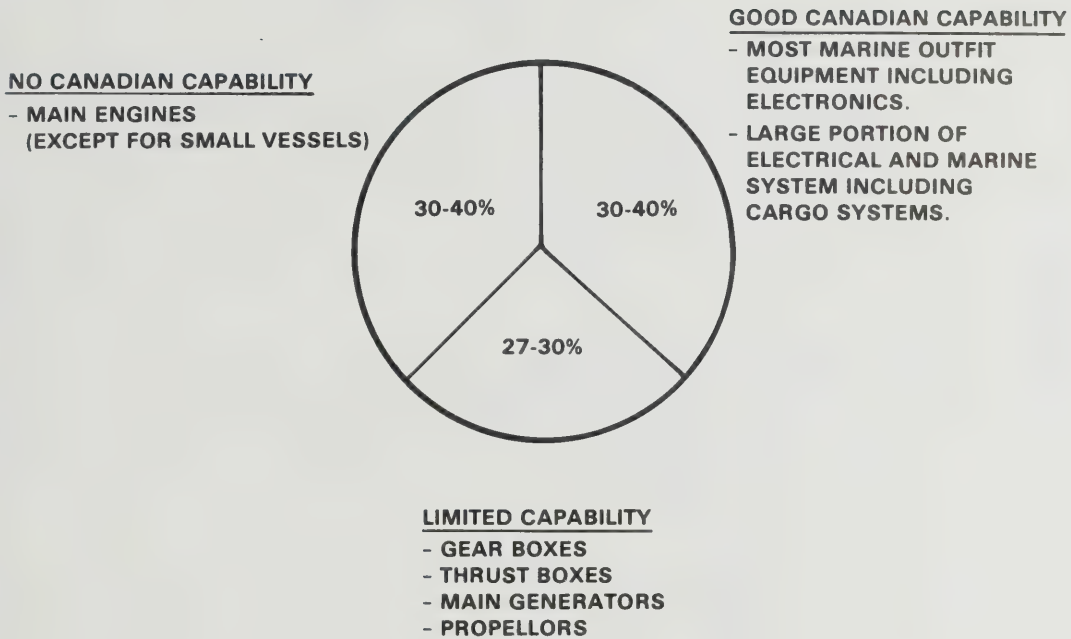
Dome sees a new shipyard as a catalyst taking the company further into training on a continuing basis, not only for its own purposes but to meet broad industry needs.

#### (f) New Shipyard Status

Numerous potential tidewater locations suitable for a new large shipyard have been examined and the alternatives reduced to a limited number of preferred sites. Design work for the new shipyard began in January, 1981 and will be substantially complete by the end of March 1982. Importantly, the specifications for shipyard equipment will also be complete in March ready for the tendering process.

Over the past nine months key managers for the shipyard have been identified and recruitment commenced. Modules for training inexperienced workers and for enhancing the skills of those with some experience are well advanced. A new training school can be operational by mid-1983.

## NEW DOME SHIPYARD



**FIGURE 6.4.4** 1982 Canadian machinery and outfit components capability.

The proposal for building a new shipyard was placed before Federal and Provincial authorities in August 1981. Since then more detailed information has been made available, supplemented by meetings and presentations.

Figure 6.4.6 sets out a timetable of the principal events envisaged from 1981 until delivery of the first Arctic Class 10 tanker.

### (g) Conclusions

Canada has tried to encourage industry to link industrial development and natural resources and to assist regional assistance programs. In the case of Beaufort Sea development plans, Dome has responded by focussing considerable attention on the marine component. The scenario of creating the technical and physical capability in Canada to efficiently build the large ships and marine structures which will be needed is well advanced.

The investments made by Dome in both financial and human resource terms has contributed a solid base of

research and development for the manufacture of large vessels and structures for the Arctic and elsewhere. Given the opportunity to follow through on its shipbuilding plans, Dome believes Canada will be placed in a uniquely strong position to benefit from this valuable technology. Overall, the economics are favourable and Dome's view is that the various Canadian industrial sectors can be ready for and can absorb with reasonable smoothness the industrial requirements of the planned new shipyard. The substantial participation by a broadly based cross-section of Canadian industry is an important and continuing benefit. Other benefits have been noted.

The expertise to undertake the construction and operation of a large new shipyard in Canada presently exists as a nucleus and is building. The planned training programs will fully address any manpower shortcomings.

The new shipyard is an important industrial opportunity for Canada which has widespread industrial and human benefits.

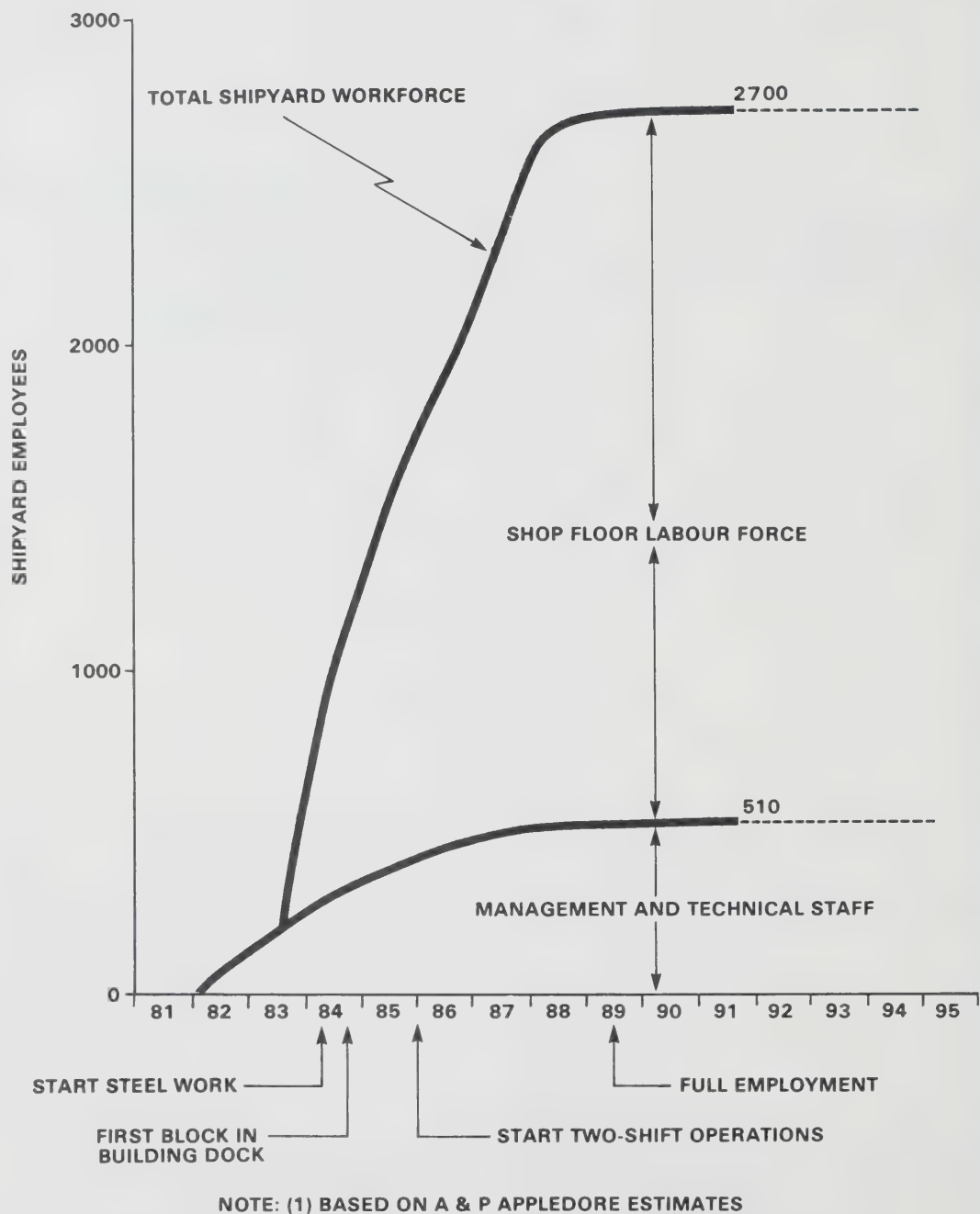
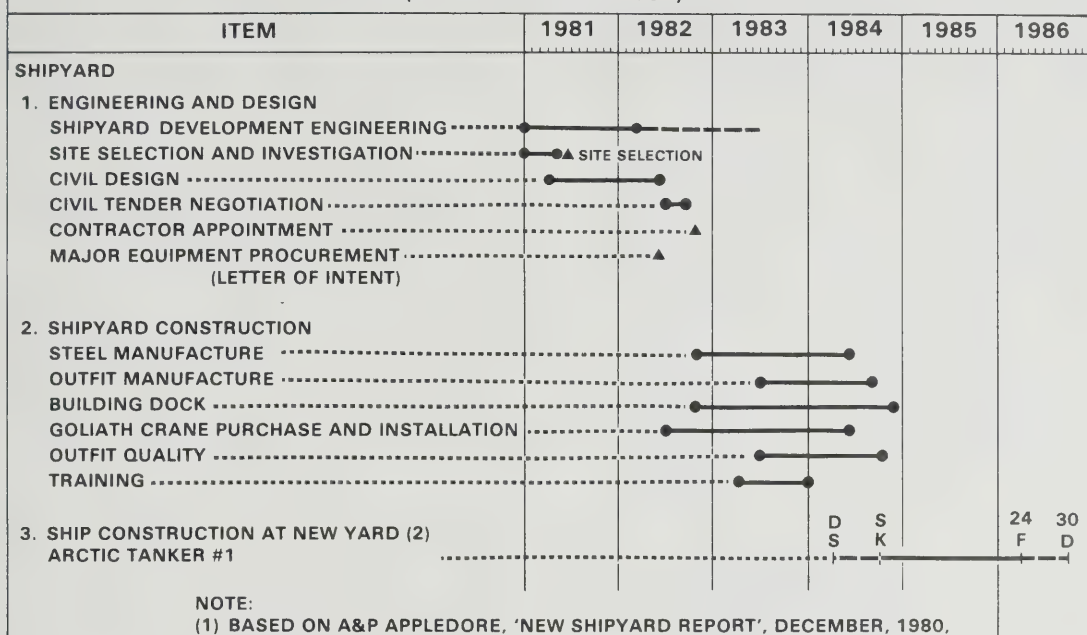


FIGURE 6.4.5 Projected build-up of staff for proposed new shipyard operations.

## SHIPYARD CONSTRUCTION SCHEDULE (REVISED MARCH 1981)



**FIGURE 6.4.6** Principal events for shipyard schedule leading to delivery of first Arctic Class 10 tankers.



7.0 DECISION-MAKING PROCESS

The Senate Committee has requested representations regarding the decision-making process. We therefore take this opportunity to briefly review the present status of regulatory procedures, and to present some recommendations for your consideration.

7.1 GENERAL CHARACTERISTICS OF CURRENT SYSTEM

Canada's North is one of the most regulated areas of the world, ensuring that development is carried out in an environmentally and socially acceptable manner. Public participation has been well developed to ensure meaningful input from local residents. As a result, tangible benefits have accrued to northern residents in the form of jobs, training and a variety of significant business opportunities.

Dome, in its own right, has responded to northern Federal policy. Normal business practice has included discussions with hunters and trappers and communities to resolve concerns in socio-economic and environmental areas. We believe we operate in the spirit of good environmental and social policy on a daily basis. While this may be, in a sense, peripheral to the mainstream of the regulatory process, we believe it directly addresses the purpose and intent of the current array of acts and regulations governing the devel-

opment of the north.

Appendix A is a recent government draft chart of government agencies, committees, etc., involved in a wide range of regulatory or advisory reviews. Appendix B is an industry draft interpretation of the interrelationships in the decision-making process in development.

Clearly, the legislation and process is very comprehensive with stringent control on virtually every aspect of oil and gas activity. At the compliance level, the system is effective in terms of yielding decisions, perhaps not as quickly as industry would like at times, but usually in time to meet seasonal imperatives. At the policy level the generally perceived lack of clear definition for northern hydrocarbon development, is resulting in industry being apprehensive about making the major commitments required before any significant development can take place. The Environmental Assessment and Review Process and regulatory agencies, would also benefit from a more defined statement of public policy on Beaufort development.

7.2 IMPLICATIONS FOR EARLY PRODUCTION — A CASE STUDY

Notwithstanding the positive aspects of the Canadian regulatory processes, Dome perceives some problem areas. We offer the following case study as an example.

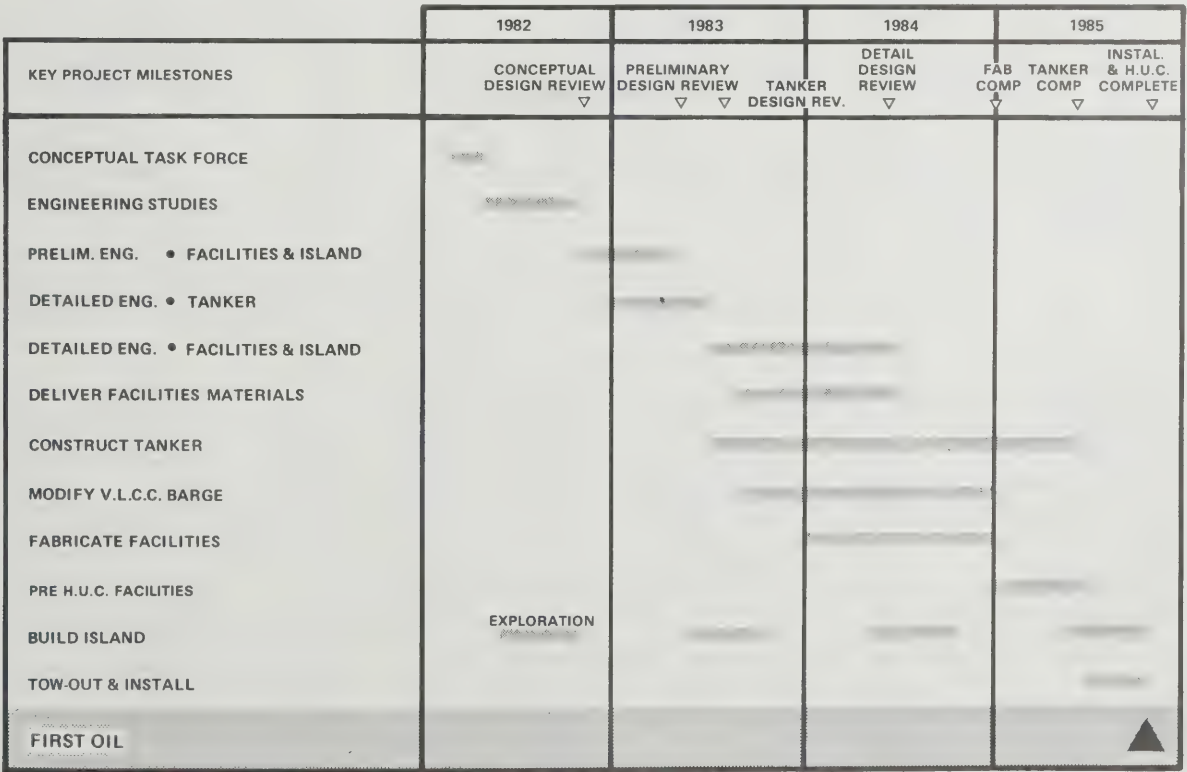


FIGURE 7.2.1: Technically feasible schedule for achieving early oil production by 1985.

The framework for the regulatory decision-making process for the production of oil and gas from the Beaufort Sea has already been established by law. However, the development of the organizations and procedures necessary to implement the process is not yet complete. Dome is concerned that the development of the procedures will not support an early oil production schedule. Action is required to speed up the process.

A technically feasible schedule for initiating oil production up to 50,000 BOPD by 1985 from the Beaufort Sea is outlined in Figure 7.2.1. To meet this objective the Government approvals shown in Figure 7.2.2 are required as indicated. To meet this schedule many regulations presently in draft form must be approved, guidelines to support these regulations must be formulated and personnel must

be allocated to implement the regulations. Of major importance is the development of the intergovernmental agency coordination required to make the approval decisions.

The impact of a four month delay in the issuance of recommendations pertaining to the Environmental Impact Statement, for example, will result in a one year delay in obtaining first oil. This is shown in Figure 7.2.3. The one year delay results from missing the open water window required for tow-out and installation of equipment, a significant characteristic of Beaufort Sea operations. An additional one month delay in production approval could cause first oil production to be delayed until 1987. Delays of this nature would be extremely costly. It is vitally important that the regulatory process be geared to support industry's efforts to meet Canada's self-sufficiency objectives. It is

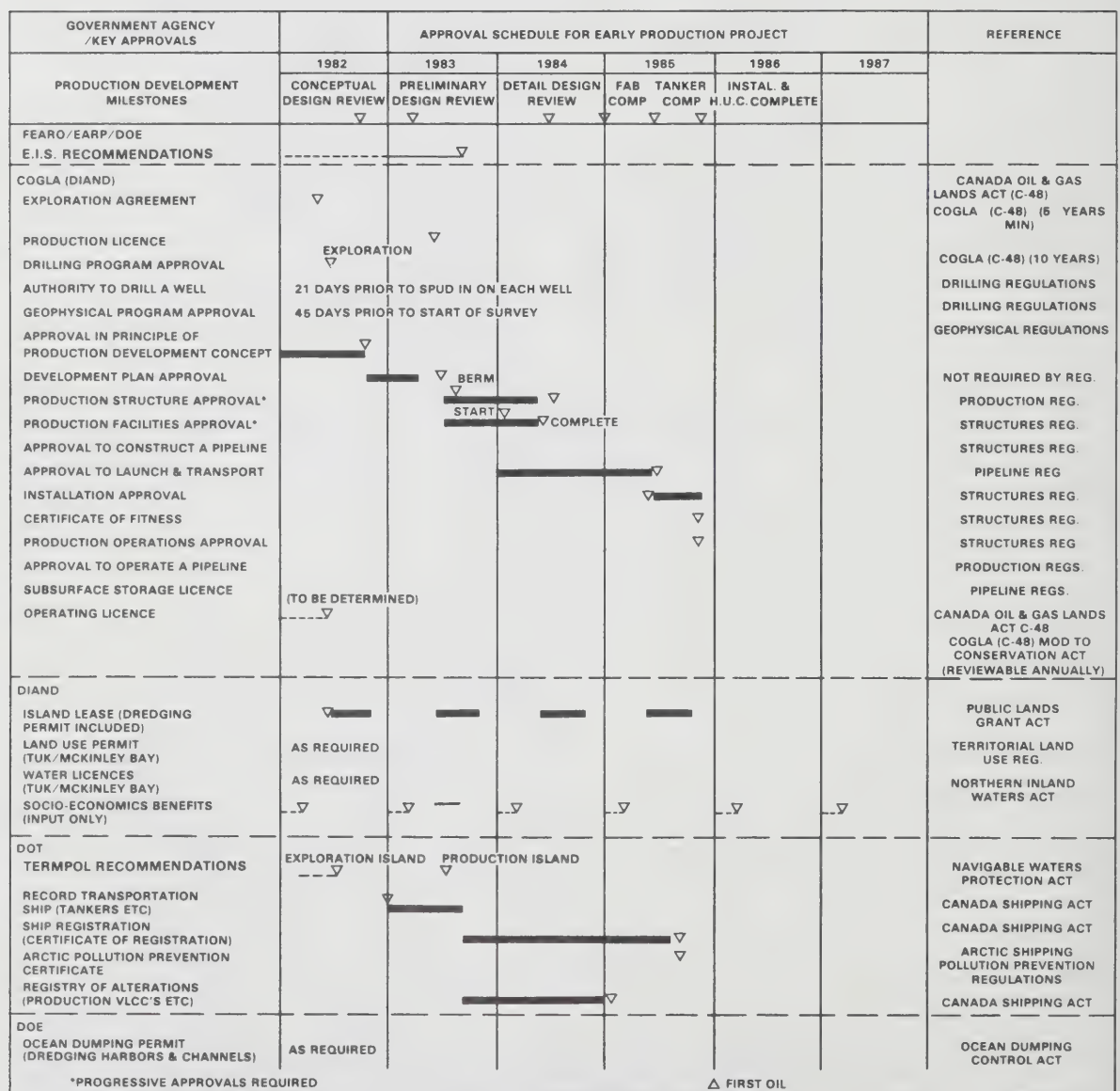


FIGURE 7.2.2: Government approvals required and projected schedule to achieve early oil production by 1985.

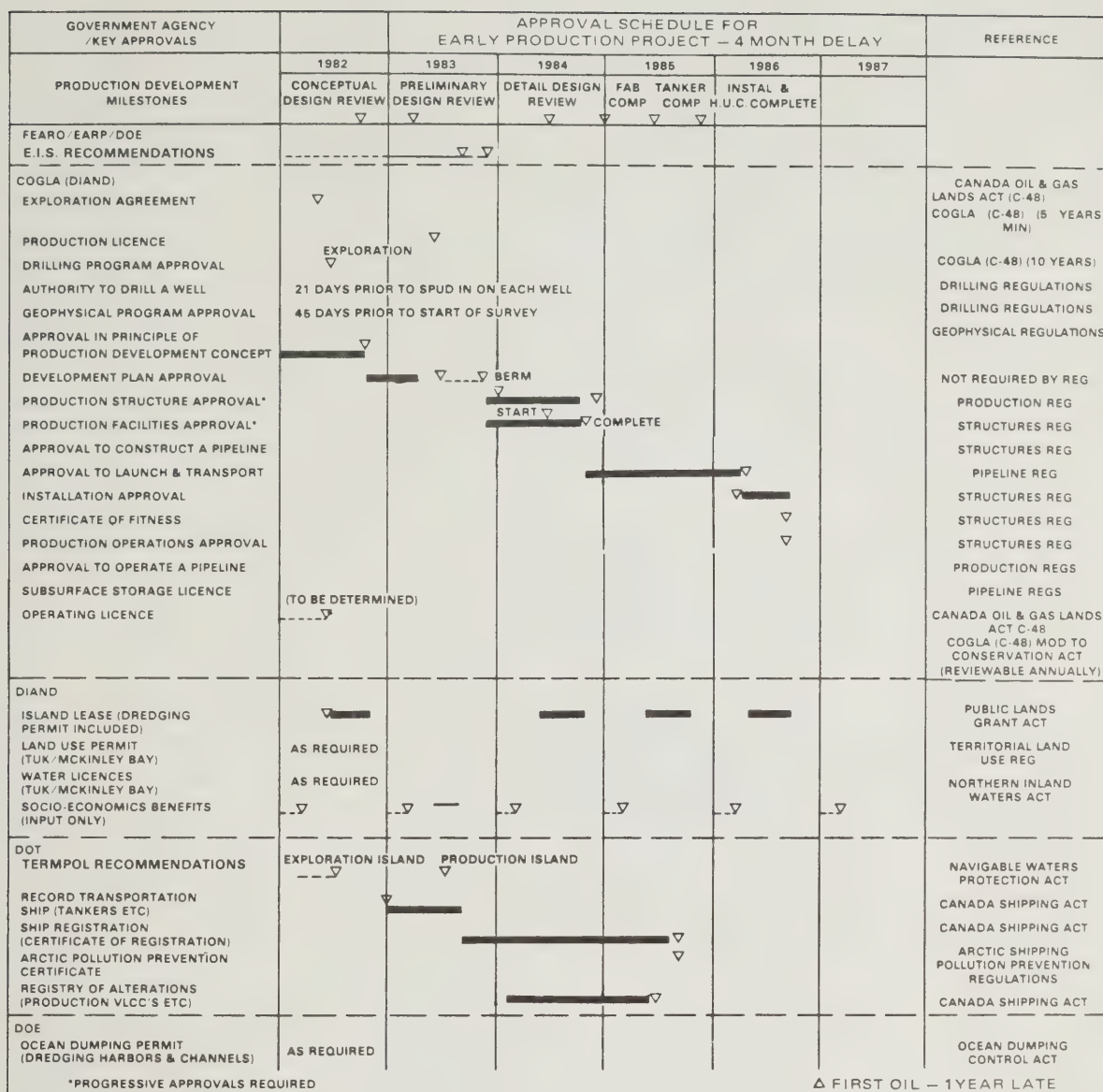


FIGURE 7.2.3: Projected impact of a 4 month delay in the issuance of EIS recommendations upon development schedule.

equally important that the oil industry cooperate and coordinate with the Government on these matters. This is Dome's intent.

## 7.3 RECOMMENDATIONS

At the compliance level which includes decisions on land use permits, dredging licences, vessel designs, structures, pipelines and plant designs, it is recommended that no major changes are necessary other than those that take place in a gradual evolutionary manner consistent with changing conditions. However, in order to initiate early oil production from the Beaufort it will be necessary to expedite the implementation of relevant regulations, guidelines and procedures.

At the policy level, the single policy statement most useful to industry, the Environmental Assessment and Review Process and regulatory agencies in general, would be an early explicit "Approval-in-Principle" for the development of Beaufort oil and gas to proceed expeditiously in the interest of the natural economy.

Conditions to such a policy statement are already fairly well established in legislation and other policies, however, the following statements would also be helpful:

1. The development rate will be determined primarily by:
  - (a) the discovery rate and available markets;
  - (b) field production rates consistent with good prac-

- tice respecting conservation of oil and gas reserves;
- (c) sound development of discoveries on a field by field basis.
2. Choice of transportation modes will reflect:
    - (a) financibility as well as profitability;
    - (b) flexibility to match changing market destination;
    - (c) capability to match changing production rates;Recognition of these conditions identifies the marine mode as an essential component of Beaufort development, especially in the early years of oil transportation.
  3. The role of the Beaufort EARP shall be to determine and recommend prudent environmental conditions consistent with the policy to develop, and regarding the use of marine and/or pipeline transportation modes.
  4. Public participation should be geared primarily to the local residents as is currently practiced in the Beaufort region, through consultations with groups such as the Beaufort Sea Community Advisory Committee, individual community Councils and Hunters and Trappers Associations.

Explicit confirmation of the above statements will not provide bankable security in themselves, however, they will influence the "comfort factor" in taking certain business risks. Furthermore, the tasks of certain review and regulatory agencies will be eased as the scope of their work will be better focused.

Finally, the continued approach to a centralized focal point for all approvals for operator's plans is recommended.







